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Scenario Analyses Concerning Energy Efficiency and Climate Protection in Regional and National Residential Building Stocks

Examples from Nine European Countries

- EPISCOPE Synthesis Report No. 3 -

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1 Introduction

(by EPISCOPE partner IWU)

The European Union has formulated ambitious CO_2 reductions and energy efficiency goals for the next decades. The potential of the housing stock to contribute to these savings is considered to be significant. In 2050 the built environment is expected to be nearly carbon neutral, with greenhouse gas emissions 88-91 % lower than in 1990 [EC 2011].

To track, steer and control the process to attain these targets, knowledge about the characteristics of European housing stocks, their current energy performance and the dynamics in refurbishment is necessary. The EPISCOPE project, co-funded by the Intelligent Energy Europe Programme of the European Union, aims to respond to these requirements by tracking the implementation of energy saving measures in residential building stocks as well as their effects on energy consumption and greenhouse gas emissions. EPISCOPE (2013-2016) is the successor of the DATAMINE (2006-2008) and TABULA (2009-2012) projects, in which the collection and evaluation of EPC data and the implementation of residential building typologies in a series of European countries were realised. Building up on these experiences and findings, the scope was extended towards the elaboration of building stock models and scenario calculations to assess refurbishment as well as energy saving processes and project future energy consumption. A long-term objective is to install regular bottom up monitoring procedures for building stocks.

This report documents methodological aspects and selected results of the scenario analyses. It covers scenario calculations conducted for regional residential building stocks in Salzburg/Austria, the Comunidat Valenciana/Spain, the Piedmont Region/Italy, the national non-profit housing stock in the Netherlands as well as the national residential building stocks in Germany, England, Greece, Norway, and Slovenia.

Thereby, the objective of the scenario analysis is not a prediction of future energy demand in the respective building stock. Rather, the objective is to show the potential future impact of predefined assumptions. This may help respective key actors and policy makers to decide on strategies and policies for transforming building stocks towards carbon dioxide neutrality.

The present report starts with a description of European climate and energy targets for the building sector in chapter 2. Chapter 3 documents the building stocks observed as well as the individual scenario approaches and results. It concludes with a summary of the main findings and conclusions in chapter 4.

In addition, scenario calculations for local building stocks (portfolios of housing companies, municipalities, districts) are compiled in the separate EPISCOPE Synthesis Report No. 2 [EPISCOPE Project Team 2016a], whereas Synthesis Report No. 4 highlights the individual procedures to collect the necessary data and information for building stock monitoring and modelling [EPISCOPE Project Team 2016b]. The individual scenario approaches and results for each of the building stocks considered are described in detailed case study reports[1]. Furthermore, data and energy balance calculations referring to the current state of the building stocks considered are included in the TABULA WebTool[2].

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[1] Available at: http://episcope.eu/monitoring/case-studies/ and http://episcope.eu/communication/download/ (case study reports in national languages)

[2] TABULA WebTool area “Building Stocks”: www.webtool.building-typology.eu

Table 1: Sources / References Introduction

Reference shortcut	Concrete reference (in respective language)	Short description (in English)
[EC 2011]	COM (2011) 112 final, Communication from the Commission to the European Parliament, The Council, the Europeans Economic and social committee and the committee of regions, A Roadmap for moving to a competitive low carbon economy in 2050. European Commission. Available at: http://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX:52011DC0112 [2015-07-24]	
[EPISCOPE Project Team 2016a]	Stein, B., Loga, T., Diefenbach, N. (ed.) (2016): Scenario Analyses Concerning Energy Efficiency and Climate Protection in Local Residential Building Stocks. Examples from Eight European Countries – EPISCOPE Synthesis Report No. 2. Institut Wohnen und Umwelt, Darmstadt. Available at: http://episcope.eu/fileadmin/episcope/public/docs/reports/EPISCOPE_SR2_LocalScenarios.pdf	EPISCOPE Synthesis Report No. 2 on scenario analyses in local building stocks (portfolios of housing companies, municipalities, city quarters)
[EPISCOPE Project Team 2016b]	Stein, B., Loga, T., Diefenbach, N. (ed.) (2016): Tracking of Energy Performance Indicators in Residential Building Stocks. Different Approaches and Common Results – EPISCOPE Synthesis Report No. 4. Institut Wohnen und Umwelt, Darmstadt. Available at: http://episcope.eu/fileadmin/episcope/public/docs/reports/EPISCOPE_SR4_Monitoring.pdf	EPISCOPE Synthesis Report No. 4 on data collection for building stock monitoring and recommendations for monitoring activities on a regular basis

2 EU Climate and Energy Targets for the Building Sector

(by EPISCOPE partner BPIE)

Energy consumption in buildings accounts for roughly 40 % of Europe's total final energy consumption; energy consumption in households for 27 % [Eurostat 2015a]; these energy needs are currently predominantly met by non-renewable energies[3]. In 2012, greenhouse gas emissions (GHG) generated by households stood in the EU-28 at roughly 871,000 tonnes of CO_2 equivalents and caused 19 % of Europe's total emissions [Eurostat 2015c].

The European Union has a binding legal framework to reduce 20 % greenhouse gas emissions in the year 2020 compared to 1990 levels (Table 2). The EU Climate and Energy Package sets EU wide goals for the EU emission trading system (ETS) and national targets for the non-ETS sectors, including for the building sector[4] [EC 2008a]. These national targets[5] (see Figure 1) shall by 2020 collectively deliver approximately 10 % GHG emission reduction compared with 2005 levels [EC 2009].

Table 2: 2020 and 2030 energy and climate targets for the EU as a whole

	2020	2030
GHG emission reduction target compared to 1990 levels	**20 %**	**40 %***
RES target share in energy consumption	**20 %**	**27 %**
Energy efficiency target** energy savings compared to BAU scenario	**20 %**	**27 %*****

Note: domestic reduction; ** Voluntary target; *** to be revised in 2020 having in mind 30 % target*

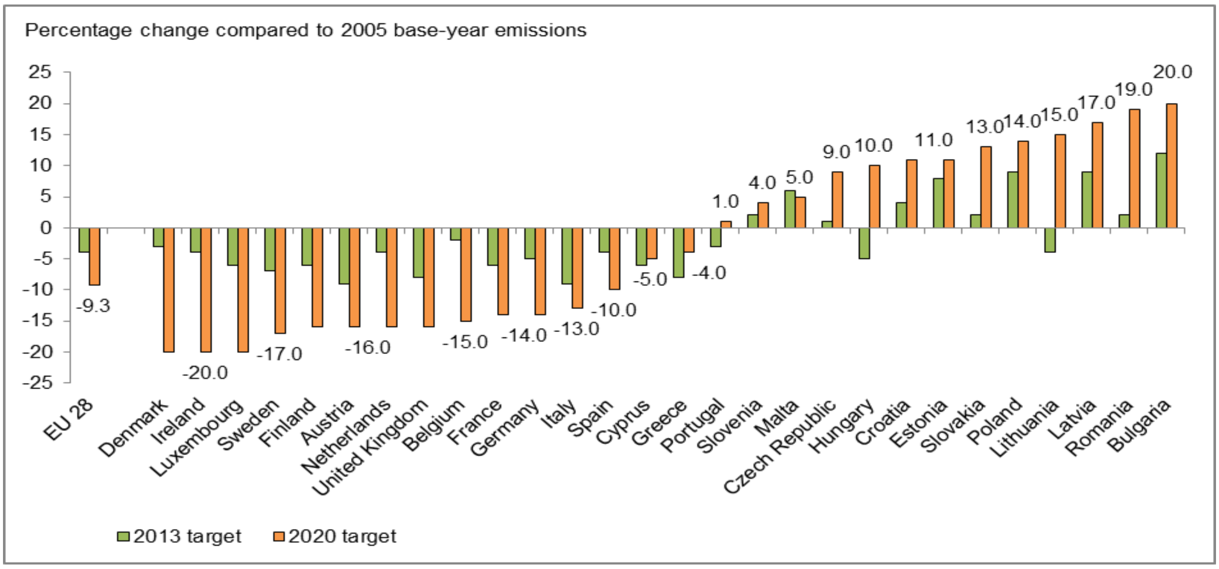

Figure 1: National 2013 and 2020 greenhouse gas emission limits under the Effort Sharing Decision, compared to 2005 emission levels [EEA 2014]

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3 In the EU-28 in 2013, the share of final energy from renewable sources in households reached 14.6 % [Eurostat 2015b].

4 The Building sector is responsible for 19 % of the total non-ETS emissions assuming that these emissions include only direct fuel consumption, as electricity consumption is mostly covered by the EU-ETS [Carbon Market Watch 2014].

5 The national targets for the non-ETS sectors (most of the sectors that are not included in the ETS, i.e. buildings, transport (excluding aviation and marine shipping) agriculture and waste), are agreed unanimously in the Effort Sharing Decision (ED) [EC 2009].

In October 2014, the European Council agreed for the 2030 framework regarding the GHG emission reduction [EC 2014a]; the target for the EU as a whole has been set for 43 % in the ETS sectors and 30 % in the non-ETS compared to 2005 levels. The European Commission made an initial proposal in February 2015 to implement the 2030 climate and energy framework [EC 2015]. It has been made clear that exploiting a huge energy efficiency potential in the building sector will be among the key priorities.

The long-term vision of GHG emission reduction has been set by the European Commission in its "Roadmap for moving to a competitive low carbon economy in 2050" [EC 2011a], [EC 2011b]. The potential for cost-effective emission reductions in the non-ETS sectors by 2050 is estimated for 66 % - 71 % (see Table 3) depending on the decarbonisation scenario.

Table 3: Emissions in ETS and Non ETS sectors [EC 2011b]

Reductions compared to 2005	2030	2050
Overall	-35 to -40 %	-77 to -81 %
ETS sectors	-43 to -48 %	-88 to -92 %
Non ETS sectors (incl. building sector)	-24 to -36 %	-66 to -71 %

The 2050 Roadmap shows also the effort of reducing greenhouse gas emissions by sector according to their technological and economic potential (see Table 4). For the EU building sector, the cost effective emission reduction by 2050 only account for 88 % - 91 % decreases of GHG emissions in 2050, compared to 1990 levels. It is mainly due to "*significant reductions in required heating from improved insulation and greater use of electricity and renewables for building heating as well more energy efficient appliances"* [EC 2011b].

Table 4: EU Greenhouse gas emission reductions overall and in different economic sectors in different decarbonisation scenarios [EC 2011b]

GHG reductions compared to 1990	2005	2030	2050
Total	-7 %	-40 to -44 %	-79 to -82 %
Sectors			
Power (CO_2)	-7 %	-54 to -68 %	-93 to -99 %
Industry (CO_2)	-20 %	-34 to -40 %	-83 to -87 %
Transport (incl. CO_2 aviation, excl. maritime)	+30%	+20 to -9 %	-54 to -67 %
Residential and services (CO_2)	*-12 %*	*-37 to -53 %*	*-88 to -91 %*
Agriculture (Non-CO_2)	-20 %	-36 to -37 %	-42 to -49 %
Other Non-CO_2 emissions	-30 %	-72 to -73 %	-70 to -78 %

Although the EU energy and climate framework set the emission reduction targets for non-ETS sectors, **there is no definite sub-sector target for buildings** (both on the EU and MS level). There are however in place a number of supportive polices that target building's energy consumption. Most significant of those are the Energy Performance of Buildings Directive [EPBD 2010] and the Energy Efficiency Directive [EED 2012] which target the energy efficiency of buildings directly, as well as the Ecodesign and Energy Labelling Directives [EDD 2009], [ELD 2010], which target the energy consumption of appliances used in buildings. Furthermore, the Renewables Directive [RED 2009] also sets requirements for buildings (Figure 2).

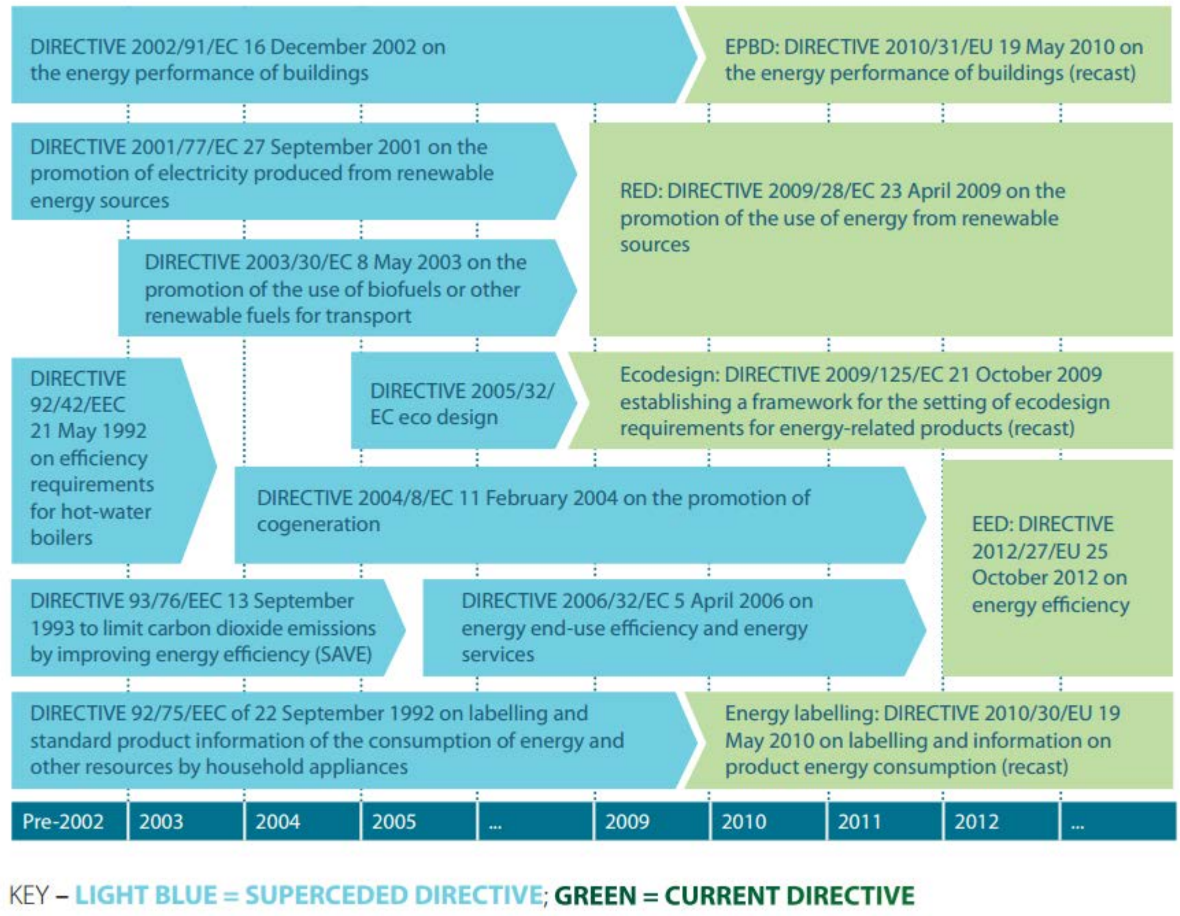

Figure 2: Timeline of key EU legislation affecting energy use in buildings [BPIE 2014]

The Energy Performance of Buildings Directive (hereafter EPBD) increases EU-wide requirements of buildings aiming to improve their energy efficiency and reduce emissions. Among the major provisions under the directive are the following:

- implementation of minimum energy performance requirements for existing buildings; in the case of a major renovation of a building (defined as one affecting 25 % of the building area or where the total cost is 25 % or more of the value of the building) (Article 7)
- development of national plans to increase the number of nearly zero-energy buildings. These national plans may include targets differentiated according to the category of building (Article 9)
- implementation of the requirements for nearly zero energy buildings; All new buildings should from 2021 be built according to nearly zero-energy standards, while owned and occupied buildings of public authorities should reach those standards in 2019 (Article 9)
- implementation of the requirements for inspections of heating and air-conditioning systems (Article 14 - 15)

Without constituting a target per se, the Impact Assessment for the EPBD [EC 2008b] quantified the minimum savings of the most beneficial options as being able to deliver a reduction of 5-6 % of the EU final energy consumption and a subsequent saving of 4-5 % of EU total CO_2 emissions in 2020.

The Energy Efficiency Directive (hereafter EED) introduces the framework to meet the non-binding target of reducing energy consumption. Buildings are important in this effort and therefore certain provisions of the directive aim specifically this sector, such as:

- the requirements for Member States to play an exemplary role in connection with buildings owned and occupied by the central Government; As from 1 January 2014, 3 % of the total floor area of such buildings shall be renovated each year to meet at least the minimum energy performance requirements set out in the EPBD (Article 5)
- preparation of a long term strategy to mobilise investment to renovate the national building stocks. This strategy has to be updated every 3 years and target public and private residential and commercial buildings. (Article 4)

The public sector is considered an important trigger for stimulating market transformation towards more efficient buildings and promoting best practice examples for low carbon measures. However, as the Coalition for Energy Savings [CES 2015] shows, the extent to which Member States are compliant with the requirement for the 3 % renovation rate is unclear and not well monitored.

Similarly, under Article 4, while most MS submitted their renovation strategies, the ambition communicated through these documents does not seem to meet the challenge of renovating the EU building stock by stimulating the market [BPIE 2014].

The Renewable Energy Sources Directive (hereafter RED) is mostly known as the legislative instrument to increase the share of renewable energy to 20 % by 2020, and while this is its main purpose, it is less known for its important requirements for buildings.

Following the ratification of the directive and under Article 13, Member States have to amend their buildings codes and regulations and introduce appropriate measures to increase the share of renewable energy - irrespectively of the kind thereof - in the building sector.

The requirements for renewable energy apply to new buildings and to buildings undergoing major renovation. It is notable that renewable energy does not need to be generated on-site, but could be provided through district heating and cooling produced to a large extent by renewable energy sources.

Specific targets are provided for biomass, where Member States are required to promote technologies that achieve a conversion efficiency of at least 85 % for residential and commercial applications and at least 70 % for industrial applications.

The Ecodesign Directive and the Energy Labelling Directive are among the most effective EU policy tools for the promotion of energy efficiency in buildings, creating a comprehensive framework for performance criteria for a product’s lifetime energy use. The Ecodesign Directive focuses on setting minimum requirements for the products’ performance, thereby reducing the final energy demand of buildings, while the Energy Labelling system aims to increase communication of a range of appliance’s energy efficiency information. Their combination removes products from the market which are wasteful users of energy while directing consumers towards better products. No energy using product can be marketed in the EU area without a guarantee that it complies with the Ecodesign Directive’s standards and an energy label is compulsory for all energy using products, in order to provide consumers with sufficient information so that they can make a choice from the featured marketed products.

Table 5: Sources / References EU Climate and Energy Targets for the Building Sector

Reference shortcut	Concrete reference (in respective language)	Short description (in English)
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[EC 2008a]	COM (2007) 2 final, Communication staff working documents Impact Assessment Accompanying document to the Communication from the Commission to the European Parliament, The Council, the Europeans Economic and social committee and the committee of regions, Limiting Global Climate Change to 2 degrees Celsius The way ahead for 2020 and beyond. Available at: http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=COM:2007:0002:FIN:EN:PDF [2015-07-24]	
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Reference shortcut	Concrete reference (in respective language)	Short description (in English)
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[EEA 2014]	European Environment Agency (EEA) (2014): Trends and projections in Europe 2014; Tracking progress towards Europe's climate and energy targets for 2020; European Environmental Agency Report No 6/2014. Available at: http://www.eea.europa.eu/publications/trends-and-projections-in-europe-2014 [2015-07-24]	
[EDD 2009]	Directive 2009/125/EC Directive 2009/125/EC of the European Parliament and of the Council of 21 October 2009 establishing a framework for the setting of Ecodesign requirements for energy-related products	
[EED 2012]	EED 2012/27/EU Directive 2012/27/EU of the European Parliament and of the Council of 25 October 2012 on energy efficiency, amending Directives 2009/125/EC and 2010/30/EU and repealing Directives 2004/8/EC and 2006/32/EC	
[ELD 2010]	Directive 2010/30/EU of the European Parliament and of the Council of 19 May 2010 on the indication by labelling and standard product information of the consumption of energy and other resources by energy-related products	
[EPBD 2010]	EPBD recast 2010/31/EU Directive 2010/31/EU of the European Parliament and of the Council of 19 May 2010 on the energy performance of buildings, amending Directive 2002/91/EC	
[Eurostat 2015a]	European Commission / Eurostat (2015): Final energy consumption by sector, tsdpc320. Last update: 10.07.2015. Available at: http://ec.europa.eu/eurostat/tgm/table.do?tab=table&init=1&plugin=1&language=en&pcode=tsdpc320 [2015-07-22]	
[Eurostat 2015b]	European Commission / Eurostat (2015): Final energy consumption in households by fuel, t2020_rk210. Last update: 10.07.2015. Available at: http://ec.europa.eu/eurostat/tgm/table.do?tab=table&init=1&plugin=1&language=en&pcode=t2020_rk2 [2015-07-22]	
[Eurostat 2015c]	European Commission / Eurostat (2015): Greenhouse gas emissions by industries and households. Data extracted in January 2015. Available at: http://ec.europa.eu/eurostat/statistics-explained/index.php/Greenhouse_gas_emissions_by_industries_and_households [2015-07-23]	
[RED 2009]	Directive 2009/28/EC of the European Parliament and of the Council of 23 April 2009 on the promotion of the use of energy from renewable sources and amending and subsequently repealing Directives 2001/77/EC and 2003/30/EC	
[ODYSSEE 2015]	Trends and Policies in the Households and Tertiary sectors. An Analysis Based on the ODYSSEE and MURE Databases. Available at: http://www.odyssee-mure.eu/publications/br/energy-efficiency-trends-policies-buildings.pdf [2015-07-24]	

3 Scenario Results

(Introduction by EPISCOPE partner IWU)

In the framework of the EPISCOPE project, scenario calculations were carried out for the regional or national residential building stocks listed below:

Regional residential building stocks

- AT - Province of Salzburg / Austria
- IT - Piedmont Region / Italy
- ES - Comunitat Valenciana / Spain

National residential building stocks

- DE - Germany
- GB - England
- GR - Greece
- NL - Non-profit rented housing stock Netherlands
- NO - Norway
- SI - Slovenia

Procedure and findings are summarised in the following subchapters: for each case study a description of the current state of the respective building stock, the scenario approach as well as the most relevant data sources is given. Furthermore, results for three different scenarios are discussed, one of them usually being the extrapolation of the current trend. The definition of the two other scenarios as well as the set-up of the building stock model was done individually by the responsible project partner. Finally, conclusions are drawn with regard to the attainment of European and individual climate protection targets.

Summary Indicators

The main results are illustrated by the use of "summary indicators"[6] as defined in [EPISCOPE Project Team 2014] and [EPISCOPE Project Team 2016], referring to the current states of the building stocks (also called "basic case" in general 2015, in some/single cases 2012), and – depending on the individual periods under review – values for 2020, 2030 and/or 2050.

[6] Documentations of the monitoring and scenario indicators can be found at the case study pages of the EPISCOPE website: http://episcope.eu/monitoring/case-studies/

The main summary indicator is the **annual carbon dioxide emission per m² EPISCOPE reference area**[7]. Included are pure CO_2 emissions caused by heating and hot water supply for the considered building stock including auxiliary energy and energy for ventilation. Not only the on-site CO_2 emissions of heating systems but also the CO_2 emissions for district heating and for electricity production (used for heat supply and auxiliary energy) are considered. CO_2 equivalents of other greenhouse gases are not included.

The second indicator is the **total heat demand**, being defined as the total of:

the energy need for space heating
+ heat losses of distribution and storage systems for space heating*
+ energy need for domestic hot water
+ heat losses of distribution and storage systems for domestic hot water.

* heat recovery by ventilation systems is not subtracted from the energy need for space heating

The third indicator is the **total CO_2 emission factor of heat supply**, being the result for the annual carbon dioxide emissions divided by the total heat demand.

Furthermore, in each subchapter a **break-down of the final energy balance to energy carriers** (gas, oil, electricity, ...) is given.

In the diagrams showing the annual carbon dioxide emissions also benchmarks are included. Those values either refer to individual (national or regional) climate protection targets or to the EPISCOPE benchmarks.

The EPISCOPE benchmarks are derived from a rough and straightforward translation of general EU climate protection targets: compared to 1990 the EU has decided a 20 % emission reduction until 2020 and a 40 % reduction until 2030. A not officially decided but widely agreed minimum climate protection target for industrial countries until 2050 is a reduction of 80 % (again related to 1990) [COM 2011].

According to [UBA 2014] the EU-15 greenhouse gas emissions were reduced by around 12 % (energy-related emissions) or 15 % (all emissions without land use changes) in the period from 1990 to 2012. Carrying out a short extrapolation it can be assumed that until 2015 an emission reduction of 13 % (energy-related) / 17 % (all) – or roughly speaking altogether of 15 % might have been reached (related to 1990). So the gap to be closed until 2020 / 2030 / 2050 would be 5 % / 25 % / 65 % (related to 1990) – or (rounded) 5 % / 30 % / 75 % related to the emission level of the year 2015. This defines the EPISCOPE benchmarks:

benchmark 2020 = 0,95 x m_{2015} x $A_{ref,2015}$ / $A_{ref,2020}$ ("2015 minus 5 %")
benchmark 2030 = 0,70 x m_{2015} x $A_{ref,2015}$ / $A_{ref,2030}$ ("2015 minus 30 %")
benchmark 2050 = 0,25 x m_{2015} x $A_{ref,2015}$ / $A_{ref,2050}$ ("2015 minus 75 %")

m_{2015} = $m_{CO2,heat\ supply,2015}$ (area-related CO_2 emissions 2015)
$A_{ref,year}$ = EPISCOPE reference area of the building stock in the year considered

These benchmarks, however, may not be over-interpreted: The straightforward breakdown of EU global emission targets to the CO_2 emissions of concrete residential building stocks does not consider the individual situation and reduction potentials compared to other countries with other climates, other sectors (like industry or traffic) or other building stocks. So a "really

[7] Various types of reference areas are being used in different countries. Therefore, during the TABULA project a common reference area was defined which was also used in the EPISCOPE project for the purpose of comparisons. The common reference area used for displaying the "summary indicators" is the conditioned floor area based on internal dimensions (incl. all areas within the thermal envelope incl. e.g. staircases etc.). The conditioned area includes all zones which are heated directly or indirectly during the heating season (all areas included in the thermal envelope). Conversion factors are given in [TABULA Project Team 2013], p. 27/28.

fair" burden sharing of emission targets – if it could ever be found – might lead to different numbers. But the EPISCOPE benchmarks provide the rough common scale, which helps to get a "quantitative understanding" of the situation in the observed building stocks.

Average Buildings

To transfer the results for the current states of the building stocks ("basic case") to a common data format, a concept of so called "average buildings" was developed during the EPISCOPE project. These are theoretical (synthetical) buildings with geometrical and thermo-physical characteristics equal to the average of a building stock subset, which they represent. The annual energy balance for heating and domestic hot water of average buildings is calculated in the same manner as for real buildings. Projections to the building stock can be done by multiplying the single building related figures with the total number of buildings.

For all case studies the basic case (existing state of the building stock) was transformed to the TABULA data structure to be displayed in form of average buildings by the "Building Stocks" area of the TABULA WebTool[8] which also includes a simplified building stock calculation procedure for checking the plausibility.

Furthermore, the concept of synthetical average buildings has been used for the building stock models of the EPISCOPE case studies for Germany, Italy and the Netherlands.

Case Study Procedure

The general procedure used to conduct the EPISCOPE case studies can be summarised as follows:

1. Definition of the „Basic Case"
   - Setting-up a coherent model of the building stock „today", e.g. 2015
   - Processing monitoring state indicators as far as possible
   - Determining model assumptions to close information gaps
   - Determining current utilisation conditions by taking into account available information

2. Calculation of the energy balance for the "Basic Case"
   - Calculating the energy balance of the building stock by considering the most important energy flows under usual boundary conditions
   - Processing energy consumption data (monitoring indicators) to validate or calibrate the energy balance model

3. Carrying out scenario analysis
   - Defining a trend and 2 to 4 other scenarios
   - Projecting the development of energy consumption

[8] TABULA WebTool / Area "Building Stocks". http://www.webtool.building-typology.eu/

4. Documentation of scenario indicators and results
   - Recording scenario indicators and results (information for experts) for certain years e.g. 2020, 2030, 2040, 2050 (state indicators and energy balance indicators), see [EPISCOPE Project Team 2016]

5. Determination of summary indicators
   - Reporting summary indicators (information for non-experts) for different scenarios / years to document the compliance with energy saving / climate protection targets and to give an overview of structural development (insulation + heat supply)

6. Deduction of a simplified building stock projection to be displayed in the TABULA WebTool
   - Defining „Average Buildings“ for the most relevant building types of the basic case [EPISCOPE Project Team 2016]

Table 6: Sources / References Introduction Scenario Results

Reference shortcut	Concrete reference (in respective language)	Short description (in English)
[COM 2011]	European Commission (2011): Communication from the Commission to the European Parliament, the Council, the European Economic and Social Committee and the Committee of the Regions: A Roadmap for moving to a competitive low carbon economy in 2050. Available at: http://eur-lex.europa.eu/resource.html?uri=cellar:5db26ecc-ba4e-4de2-ae08-dba649109d18.0002.03/DOC_1&format=PDF [2015-06-08]	With its “Roadmap for moving to a competitive low-carbon economy in2050” the European Commission is looking beyond the 2020 objectives for climate and energy and sets out a plan to meet the long-term target of reducing domestic emissions by 80 to 95 % by mid-century.
[EPISCOPE Project Team 2014]	Diefenbach, N.; Loga, T.; Stein, B. (ed.) (2014): Energy Performance Indicators for Building Stocks. First version / starting point of the EPISCOPE indicator scheme, March 2014, Available at http://episcope.eu/fileadmin/episcope/public/docs/reports/EPISCOPE_Indicators_FirstConcept.pdf [2015-11-29]	EPISCOPE report on energy performance indicators for building stocks
[EPISCOPE Project Team 2016]	Diefenbach, N.; Loga, T.; Stein, B. (ed.) (2016): Application of Energy Performance Indicators for Residential Building Stocks Experiences of the EPISCOPE project, March 2016. Available at: http://episcope.eu/fileadmin/episcope/public/docs/reports/EPISCOPE_Indicators_ ConceptAndExperiences.pdf	EPISCOPE report on the application of energy performance indicators for building stocks
[TABULA Project Team 2013]	Loga, T.; Diefenbach, N. (2013): TABULA Calculation Method – Energy Use for Heating and Domestic Hot Water. Reference Calculation and Adaptation to the Typical Level of Measured Consumption. Available at: http://episcope.eu/fileadmin/tabula/public/docs/report/TABULA_CommonCalculationMethod.pdf [2015-09-17]	Report on the TABULA calculation method
[UBA 2014]	Umweltbundesamt (2014): “Treibhausgas-Emissionen der EU-15 nach Quellkategorien in Mio. t CO_2-Äquivalenten”. Available at: http://www.umweltbundesamt.de/sites/default/files/medien/384/bilder/dateien/2_tab_thgemi-eu15_kategorien_2014-08-14.pdf [2015-06-08] Based on: European Environment Agency (EEA) (2014): Annual European Union greenhouse gas inventory 1990–2012 and inventory report 2014. Submission to the UNFCCC Secretariat, Publications Office of the European union, Luxwmbourg	Table summarising EU-15 greenhouse gas emissions in CO_2-equivalents by source categories; Results in- and excluding Land Use activities and Land-Use Change and Forestry (LULUCF) activities

3.1 <AT> Austria

Regional Residential Building Stock of the Province of Salzburg

(by EPISCOPE partner AEA)

In the context of the Austrian energy strategy significant CO_2 reduction potentials in the building sector (energy used for space heating and domestic hot water) have been identified. Through efficiency improvements (e.g. improved thermal insulation and boiler exchange) and the use of fuels with lower carbon content (in particular biomass fuels) and district heating the defined target value (10 million tonnes of CO_2 equivalent) in the building sector for 2013 was already reached in 2011 [BMLFUW 2015]. The discourse among the national stakeholders on Austrian energy strategy objectives and goals for 2030 is ongoing.

Observed Building Stock and Aims of the Scenario Analysis

The Austrian pilot project of EPISCOPE concerns the housing stock of the province of Salzburg, which has set ambitious goals in its EEAP [Salzburg 2015]. Its short-term goals till 2020 are a reduction of greenhouse gas emissions by at least 30 % compared to the emissions in 2005 and an increase of the share of the renewables up to 50 %. Till 2040 100 % of the energy used for space heating in buildings is planned to be provided by district heating and renewables. These goals have emerged on the basis of the targets of the national plan for the nearly zero energy buildings 2020.

Table 7: Scope of the observed building stock in <AT> Austria
*****[Statistic Austria 2014a]; **[Kurz/Filipp 2014]

Scale	No. of dwellings	No. of buildings	No. of inhabitants	m² national reference area	m² EPISCOPE reference area
Regional	> 282,800*	> 120,400*	> 534,270**	~20.9 million (living area)[9]	~23 million

In the province of Salzburg there are more than 280,000 dwellings for more than 0.5 million inhabitants. The energetic quality of the residential buildings in Salzburg has improved in recent years thanks to subsidies for renovation measures related to energy savings, implementation of new regulations concerning a better thermal building envelope in new buildings as well as increasing use of biomass, solar thermal panels and controlled ventilation systems with heat recovery. The evaluation of the existing data in the ZEUS EPC database [ZEUS 2015] shows that the average U-value of the buildings in 2013 has decreased significantly compared to 1995.

More than half (about 57 %) of the building stock has been built before 1980. The heating energy demand of these buildings (150 – 300 kWh/m²year) is 3 to 5 times higher than the new residential buildings. The energy carrier used in this period is mainly oil or gas [AEA 2015]. Therefore, this group of residential buildings has the highest potential for reducing energy consumption and reaching the regional energy targets of the province by installing better thermal insulation and changing the energy carrier from fossils to renewables.

9 According to [Statistic Austria 2004], the average m² per dwelling in Salzburg is about 88m².

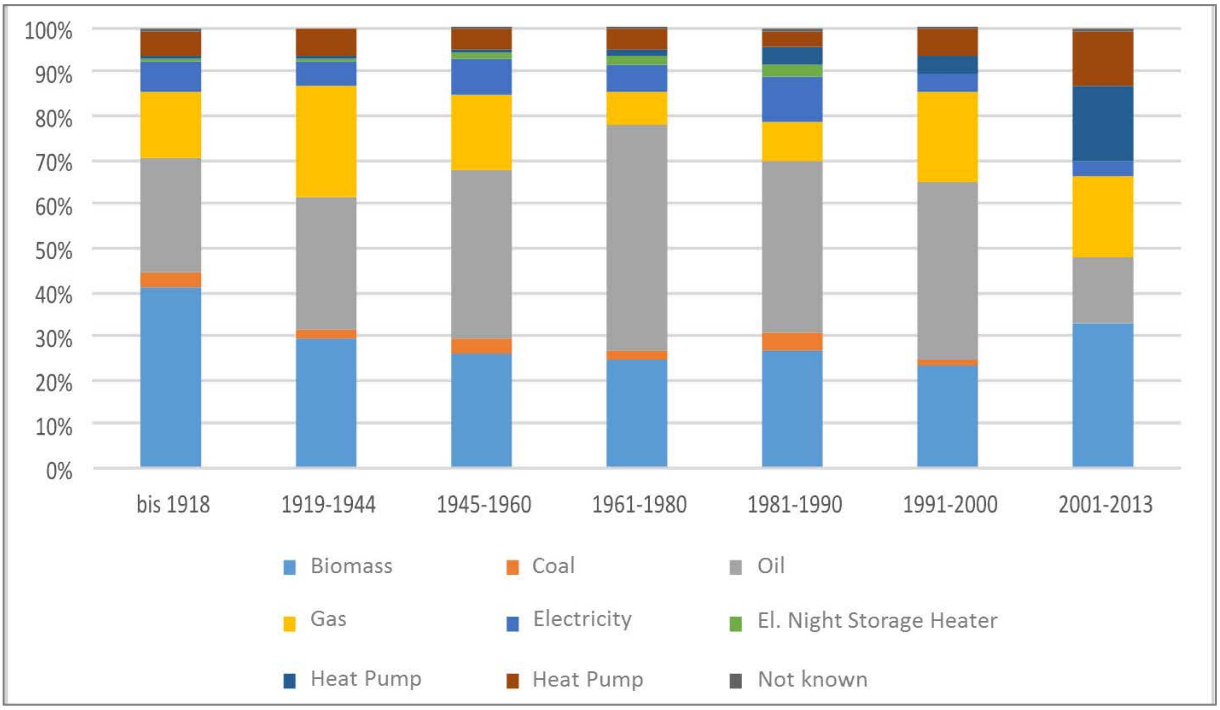


Figure 3: Share of energy carrier in the building stock of single family houses [AEA 2015]

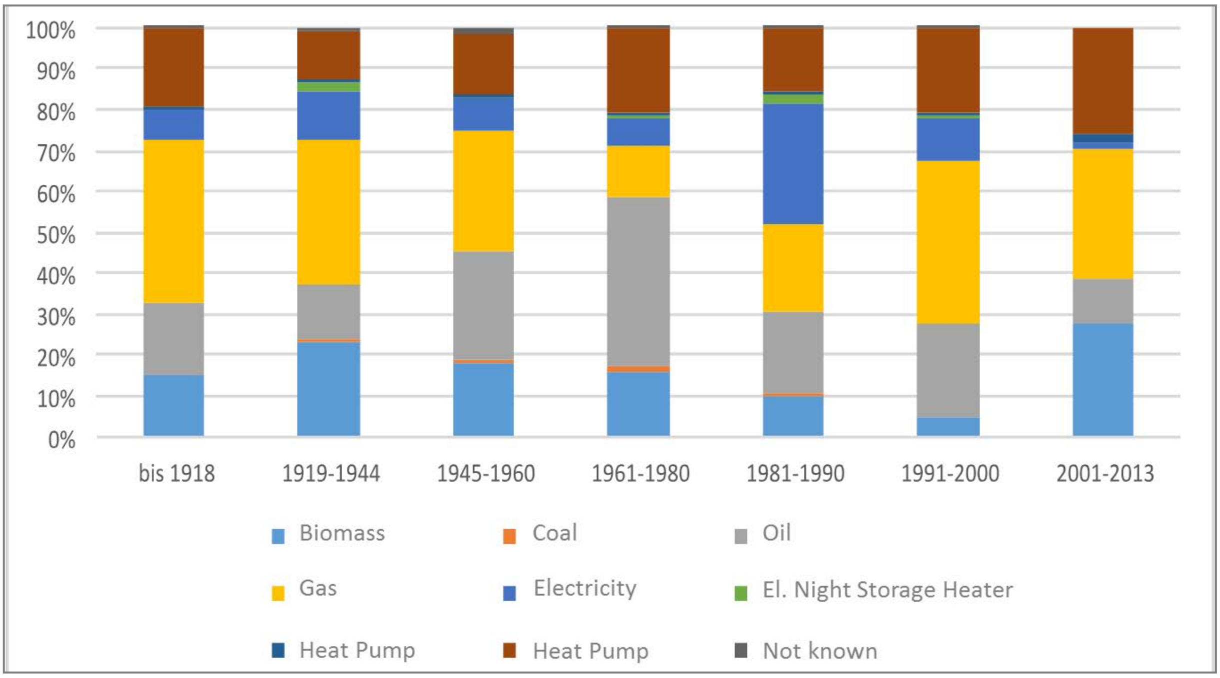


Figure 4: Share of energy carrier in the building stock of multi family houses [AEA 2015]

At the time being the renovation rate of the buildings in Salzburg is less than 1 % [BMLFUW 2015]. In 2 scenarios, the energy and CO_2–emission savings have been analysed which could be achieved by: 1) increasing the renovation rate to 3 % and 2) replacing the heating system by more environment-friendly systems such as biomass and district heating while raising the renovation rate. The analysed scenarios have their main focus on buildings built before 1980 for the renovation activities and future buildings with the building regulation according to the Austrian national plan for the NZEBs 2020.

Scenario Approach

To be able to carry out a well-grounded analysis, the available EPCs from the ZEUS-database [ZEUS 2015] were studied. In the province of Salzburg, the online EPC database ZEUS collects data on the building stock, refurbishment measures, and the development of energy efficiency of buildings and the statistical analysis of this data is provided online. For the Austrian pilot action more than 30,000 EPCs from this database were considered.

277 of these buildings – all multi family houses – upload the information on the actual energy consumption in an online programme called “energy accounting”, which is hosted by the same entity hosting the EPC database. At the beginning of the project, the comparison between the energy used and the energy calculated was intended to be used as service (or correction) factor for the calculation of the future energy demand. But the available data was not sufficient (e.g. due to the lack of regular entry) to estimate the mentioned service factor for each building type (single family and multi family houses). Therefore an excel tool was developed in order to calculate the saving potentials of the heating and domestic hot water systems for all residential building types.

The available data on the building stock (age band, size, quality of the thermal envelop, energy carrier and demolition rate including the seasonal performance factor of the heating systems, use of solar thermal energy in heating and DHW), with the exception of the user’s behaviour, were considered for the estimation of energy needs.

Data Sources

The main source of information for this project was ZEUS EPC database and the Statistics Austria. In the province of Salzburg, the online EPC database ZEUS [ibidem], introduced in 2004, collects and statistically analyses data on the building stock, refurbishment measures, and the development of energy efficiency of buildings. The main motives for the data collection for residential buildings are regional housing subsidies for individuals and non-profit housing associations, and the administration of provincial and municipal property for non-residential buildings.

The energy accounting module of the ZEUS database records data of energy generation (e.g. solar-thermal energy or heat pumps) and energy consumption (e.g. of fossil fuels, district heating or electricity).

The data such as the number of buildings, sizes of the buildings according to their age band and category as well as used energy to the square meters in the buildings and energy carrier is regularly collected and analysed by Statistics Austria [Statistik Austria 2014a], which is an independent national institution. The final consumption of energy for the province of Salzburg used for modelling the scenarios in this project is based on the data available in the documentations of this source and the sources related to the use of energy in Austria [Statistik Austria 2014b].

Description of the Basic Case and the Most Relevant Scenarios

The objectives of the province of Salzburg for 2050 in terms of energy are to be carbon neutral, energy independent and sustainable.

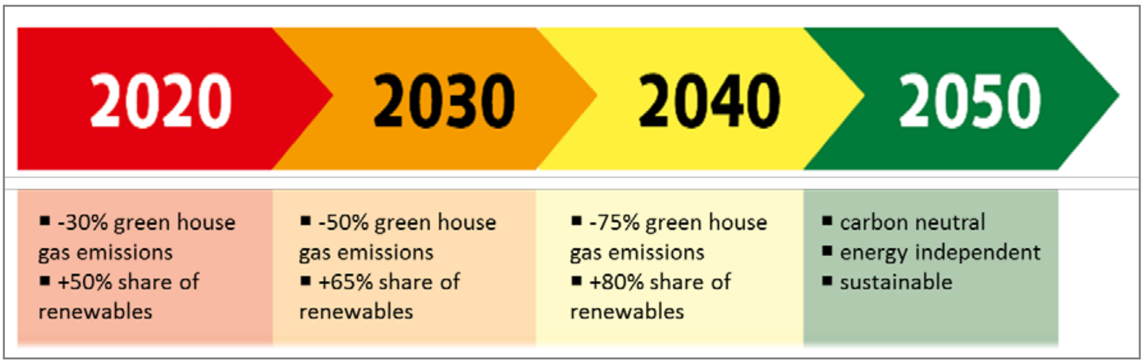


Figure 5: Short, middle and long term goals of the Province of Salzburg, greenhouse gas reductions compared to the emissions in 2005 [Salzburg 2015]

The long tradition of soft loans and grants for energy efficiency measures in the improvement and replacement of the heating system and use of renewables as energy carriers as well as improvement of the building envelope has affected the energy used in the residential building sector in Austria. Since 1993, Salzburg provides incentives for energy saving measures and the use of renewable energy sources for new residential buildings and renovations such as use of pellets and biomass, district heating, heat pumps, solar thermal panels and photovoltaic as well as implementing good thermal insulation for the building envelope.

According to the available data, in 2013 the residential sector in Salzburg used 3,609 GWh of space heating and the share of renewables and district heating (65 % of the energy is produced by renewable sources) make about 59 % of the total amount [Statistik Austria 2014b]. The trend indicates that this share could grow up to 68 % and therefore CO_2-emissions could be reduced about 17 %, if the trend in implementing the measures continued till 2020 (base scenario).

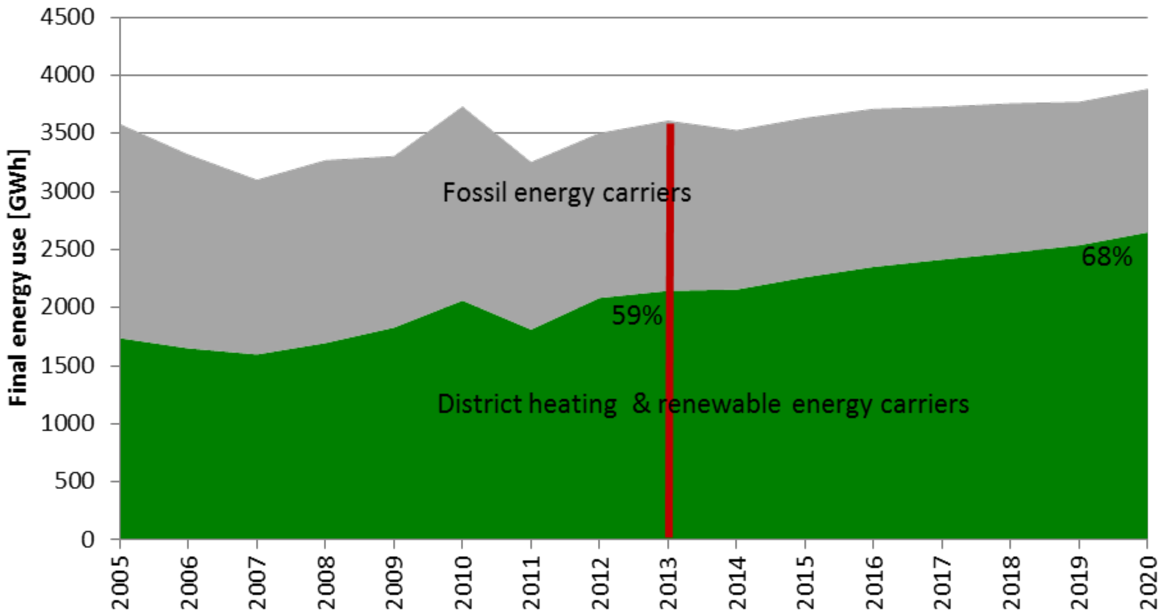


Figure 6: Share of district heating and renewable energy carrier in the space heating of residential buildings and its trend till 2020 (the source of data till 2013: [Statistik Austria 2014b], after 2013 [AEA 2015])

The evaluation of data in the renovated residential building sector shows the reduction of space heating demand by almost 65 %:

Table 8: Average of the space heating demand of the residential buildings (single and multi family houses) before and after the renovation in the ZEUS EPC database in kWh/m²a [ZEUS 2015]

Building type / age band	Existing building	Renovated in 2013
SFH		
Before 1919	166.16	50.35
1919-1945	202.75	63.78
1945-1960	178.89	67.52
1960-1980	157.28	63.93
1980-1990	116.27	65.47
MFH		
Before 1919	139.74	43.07
1919-1945	197.91	33.75
1945-1960	147.53	53.70
1960-1980	127.45	42.15
1980-1990	86.37	54.62

According to the data collected in the EPC-database ZEUS and by Statistics Austria, the energy carrier coal does no more play an important role in the residential building sector (0.2 %). In all new building categories – single family and multi family houses – the trend can be seen towards the use of biomass, heat pumps and district heating. In the renovation measures of the building stock mainly the standard constant temperature non-condensing boilers are replaced by the more efficient condensing boilers.

The scenarios examined in the project are:

1) Increasing the renovation rate up to 3 % with focus on the buildings built before 1980
2) Increasing the share of renewable energy carriers such as biomass and district heating and increasing the renovation rate

The resulted effects are evaluated in energy used [GWh/year] and CO_2-emissions [kg/m²year] and the savings are compared with the basic scenario.

Results

With the calculation tool developed in the project, the prognosis of the energy demand in the residential building sector in Salzburg could be done with acceptable results till 2030. In the calculation of the energy produced by energy carriers, the share of district heating and renewables together is compared to the fossil energy (as defined in the energy strategies of Salzburg).

Basic scenario) The development of energy used in the residential building sector with the current measures could reduce the CO_2-emissions by 31 %.

Scenario B) For this scenario the renovation rate was increased up to 3 % with focus on the buildings built before 1980. Increasing the renovation rate could effect up to 38 % reduction of the CO_2-emissions till 2030 if the share of district heating and renewable energy carriers develops as in the basic scenario. This measure would need:

- Massive promotion of the renovation activities and the relating incentives by information campaigns.
- Adapting the building regulation regarding the small and major renovations of the building envelope (façade and the windows).

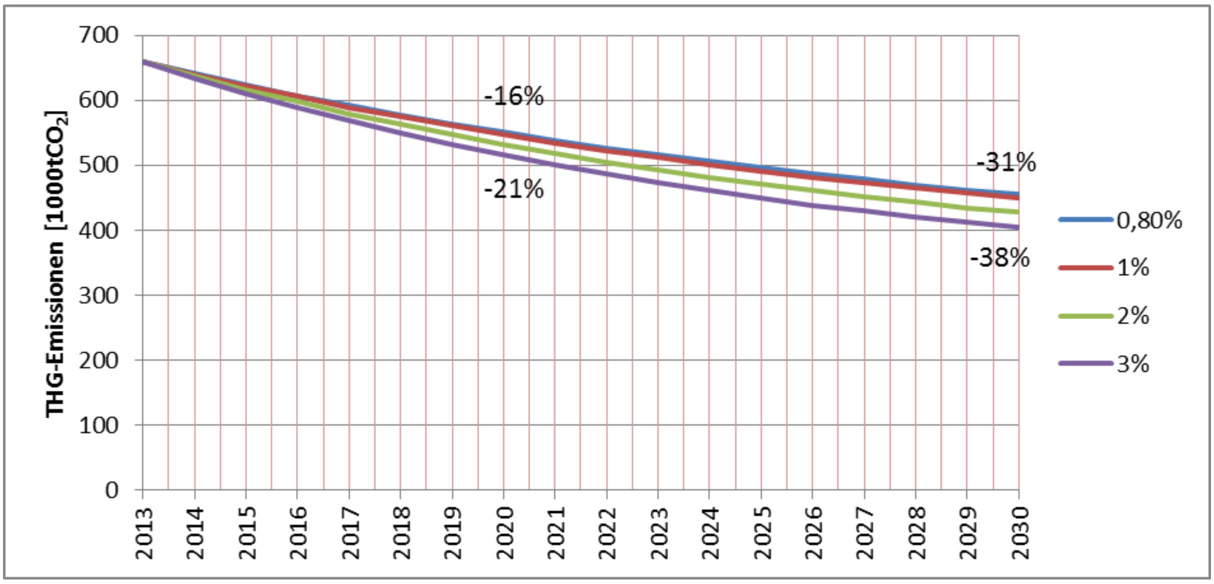


Figure 7: Progress of THG-emissions by increasing the renovation rate of the residential building sector in Salzburg (Trend and B)

Scenario C) For this scenario the share of renewable energy carriers is increased significantly: in the single family houses the share of biomass and heat pumps and in the multi family houses the share of district heating as main energy carrier was increased. This would reduce the CO_2-emissions between 35 % and 42 %.

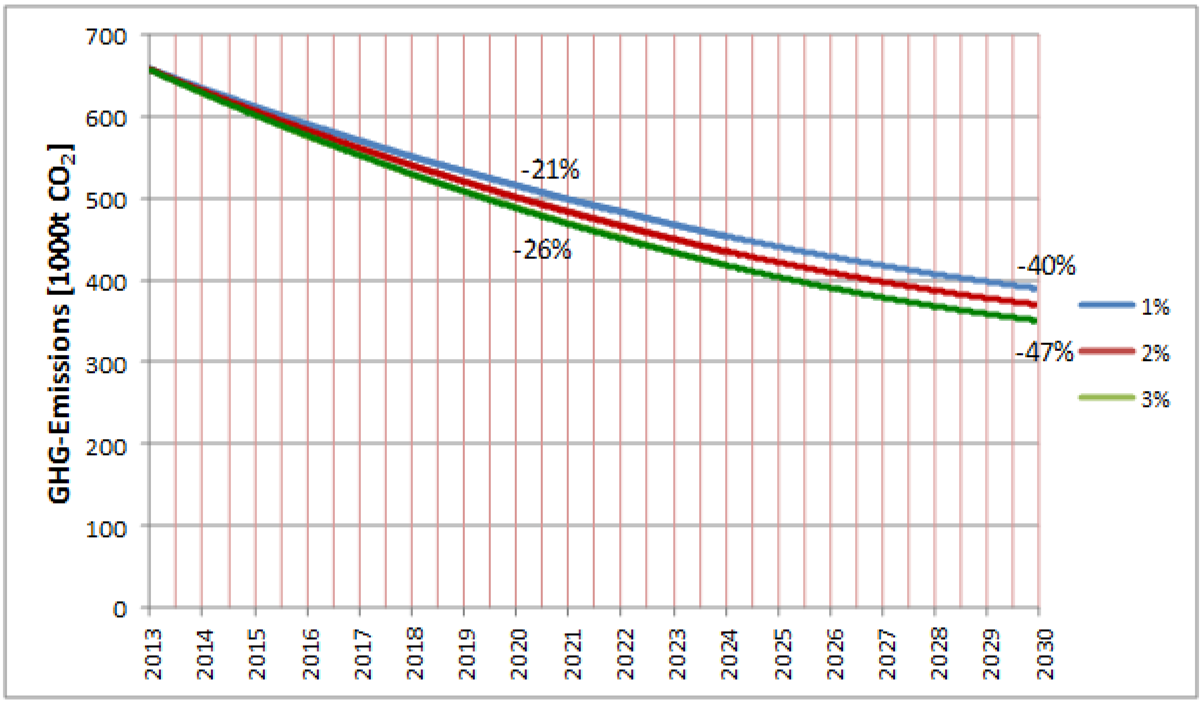
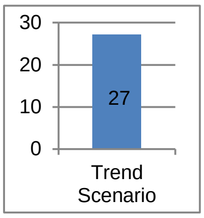
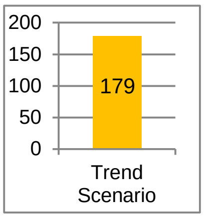
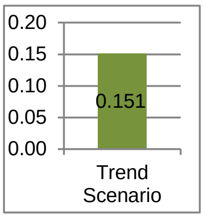
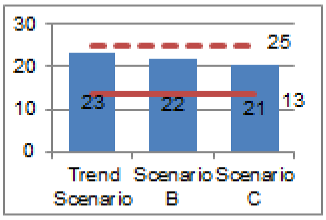
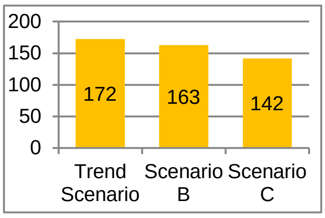
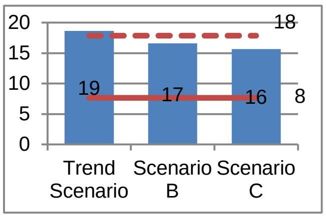
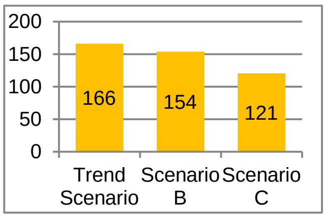
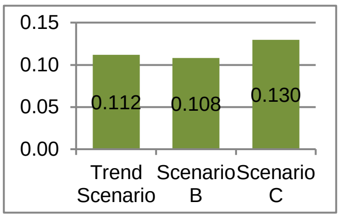
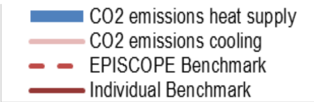


Figure 8: Progress of GHG-emissions by increasing the biomass and district heating in combination with different renovation rates (scenario B and C)

Table 9: Summary Indicators <AT> Austria

<table>
<tr><th></th><th>EPISCOPE Ref. Area</th><th>CO_2 emissions</th><th>Total heat demand</th><th>CO_2 emission factor heat supply</th></tr>
<tr><td></td><td>10^6 m²</td><td>kg/(m²yr)</td><td>kWh/(m²yr)</td><td>kg/kWh</td></tr>
<tr><td>2015</td><td>22.98</td><td>
</td><td>
</td><td>
</td></tr>
<tr><td>2020</td><td>23.67</td><td>
</td><td>
</td><td>
</td></tr>
<tr><td>2030</td><td>24.38</td><td>
</td><td>
</td><td>
</td></tr>
<tr><td>2050</td><td></td><td></td><td></td><td></td></tr>
<tr><td colspan="5">Explanation</td></tr>
<tr><td></td><td></td><td>$m_{CO2,heat\ supply}$:
annual carbon dioxide emissions (related to EPISCOPE reference area)
$m_{CO2,heat\ supply} = q_{total} \times f_{CO2,heat\ supply}$

</td><td>q_{total}:
total heat demand
(heat generation for space heating and DHW, related to EPISCOPE reference area)</td><td>$f_{CO2,heat\ supply}$:
total CO_2 emission factor of heat supply</td></tr>
</table>

The individual benchmarks relate to the maximum values in Austrian national plan for nearly zero energy buildings 2020 [OIB 2014] for the residential buildings excluding the emissions for house hold electricity demand (electricity for appliances). These values defined in the OIB-document will be implemented in the building regulations of the Länder (Austrian provinces).

Table 10: Final energy by fuel <AT> Austria, gross calorific value [GWh/yr]

	2015	2020			2030			2050		
Absolute figures	Trend Scenario	Trend Scenario	Scenario B	Scenario C	Trend Scenario	Scenario B	Scenario C	Trend Scenario	Scenario B	Scenario C
natural gas	794	770	725	638	712	626	438			
liquid gas+oil	1187	925	860	892	631	563	384			
oil										
coal	217	206	195	146	187	173	57			
wood / biomass	1020	897	831	932	732	631	744			
district heating	399	465	435	466	500	427	569			
electric energy (used for heat supply)	330	362	349	282	376	353	244			

Conclusions

According to Statistics Austria more than 65 % of the buildings in Salzburg [Statistik Austria 2004] were built before 1980. About 73 % of them were built in the period between 1945 and 1980. Concerning the quality and life cycle of the building elements and heating system such as windows and boilers, this category has a large potential in implementing energy efficiency measures as documented in the EPC-database ZEUS. The evaluation of the available data in the EPC-database shows that the average overall U-value has decreased significantly from 0.74 to 0.44 W/m^2K (this includes the building stock till 2013 in the ZEUS EPC-database).

To achieve the goals in Salzburg in reducing CO_2-emissions, it is necessary not only to change the energy carrier from fossil fuel to renewables, but also to reduce the final energy consumption, since the potential of renewable energy sources is limited [AEA 2014]. The GHG-emissions have decreased by around 15 % since 1990 in the residential building sector but the objectives of the climate protection and energy in Salzburg cannot be achieved by enforcing only one or a small group of measures.

Implementation of energy efficiency measures for achieving the goals can be summarised in:

- Subsidies play an essential role in achieving the goals
    - Subsidies for automatisation and control for heating systems,
    - Subsidies for new buildings in combination with infrastructure and urban areas,
    - Focus on renovation to increase the rate – especially among the buildings built before 1980s – by increasing consultancy in energy efficiency measures, increasing the subsidies for the major renovations optimising the insolation thickness in relation to the life cycle of the building,
- Increasing the inspection of the energy efficient measures and implementation of smart metering,
- Increasing installation of solar thermal panels and PV systems,
- Replacing fossil energy carriers through renewables systems,
- Increasing information campaigns not only for the energy efficiency in buildings and building compliances but also users' behaviour,
- Accelerate the trainings for the professionals for energy efficient and sustainable heating systems and constructors,
- Implementation of regular inspecting and optimising the heating systems,
- Use of near-surface and deep geothermal energy.

Sources / References <AT> Austria

Table 11: Sources / References <AT> Austria

Reference shortcut	Concrete reference (in respective language)	Short description (in English)
[AEA 2014]	Tretter, H./Krutak, R./Zach, F./Krutzler, T/Ibesich, N. (2014): Potenziastudie zum „Masterplan Klima-schutz & Energie 2020". Österreichische Energie-agentur/Austrian Energy Agency (AEA), Wien	A study on the potencials of the master plan for the climate protection and energy 2020
[AEA 2015]	Altmann-Mavaddad, N./Simander, G./Solacher, E./Tretter, H. (2015): Energetische Qualität und Sanierungstrends des österreichischen Wohnge-bäudebestands mit Folus auf die Sanierungsent-wicklung in Salzburg. Österreichische Energiea-gentur/Austrian Energy Agency (AEA), Wien, unpublished manuscript	Analysis oft he renovation activities and strategies in Salzburg 2015 (Austrian Pilot Project in EPISCOPE)
[BMLFUW 2015]	Bundesministerium für Land- und Forstwirtschaft, Umwelt und Wasserwirtschaft (2015): Maßnahmen im Gebäudesektor 2013, Bericht des Bundes und der Länder nach Art. 15a B-VG Vereinbarung BGBL. II NR. 251/2009. Avialable at: http://www.bmlfuw.gv.at/umwelt/klimaschutz/klimapolitik_national/Wohnbau.html [2015-06-19]	Report on measures and activities oft he federal government and the Austrian provinces published in 2015
[Kurz/Filipp 2014]	Kurz, Peter/Filipp, Gernot (2014): Bevölkerung Land Salzburg Stand & Entwicklung 2014. Availa-ble at: http://www.salzburg.gv.at/statistik_daten_bevoelkerung_2014.pdf [2015-06-19]	Status and development oft he population oft he province of Salzburg 2014
[OIB 2014]	Österreichisches Institut für Bautechnik (2014): OIB Dokument zur Definition des Niedrigstener-giegebäudes und zur Festlegung von Zwischen-zielen in einem „Nationalen Plan" gemäß Artikel 9 (3) zu 2010/31/EU, 28. März 2014, Available at: http://www.oib.or.at/sites/default/files/nationaler_plan.pdf [2015-06-24]	Nearly Zero Energy buildings 2020 in Austria, 2014
[Salzburg 2015]	Land Salzburg (2015): Klima- und Energiestrategie SALZBURG 2050, Available at: http://www.salzburg.gv.at/aktuell/salzburg2050.htm [24.06.2015]	The climate protection and enrgy strategy for Salzburg 2050
[Statistik Austria 2004]	Statistik Austria (2004): Gebäude- und Wohnungs-zählung. Hauptergebnisse Steiermark, Wien, Verlag Österreich, Available at: http://www.statistik.at/web_de/services/publikationen/7/index.html?includePage=detailedView&publd=123&sectionName=Wohnen [2015-05-28]	Statistic Austria building and dwellings 'register 2001
[Statistik Austria 2014a]	Statistik Austria (2014): Wohnen: Zahlen, Daten und Indikatoren der Wohnstatistik 2013. Available at: http://www.statistik.at/wcm/idc/idcplg?IdcService=GET_NATIVE_FILE&RevisionSelectionMethod=LatestReleased&dDocName=102995 [2015-06-24]	Statistical data on residential buildings 2013
[Statistik Austria 2014b]	Statistik Austria (2014): Energetischer Endver-brauch 2013 nach Energieträgern und Nutzener-giekategorien für Österreich (NEA), Available at : http://www.statistik.at/web_de/statistiken/energie_um-welt_innovation_mobilitaet/energie_und_umwelt/energie/nutzenergieanalyse/index.html [2015-06-24]	Final energy consumption 2013 according to enery carriers and usage categories for Austria
[ZEUS 2015]	ZEUS gizmocraft, design and technology GmbH((ed): Energieausweis Datenbank: http://energieausweise.net/technik [2015-05-28]	Austrian EPC database

3.2 <DE> Germany

National Residential Building Stock

(by EPISCOPE partner IWU)

Scenario analysis was carried out for the heat supply (heating and hot water generation) in the German residential building stock against the background of the long-term climate protection targets. The detailed results of the German EPISCOPE subproject are documented in [IWU 2015].

Basic data of the German residential building stock in 2011 are shown in Table 12. The total number of inhabitants in Germany was 78.7 million. Among those 2.9 million (3.6 %) live in apartments in non-residential buildings which are not considered in the scenarios.

Table 12: Scope of the observed building stock in <DE> Germany [SÄBL 2015]

Scale	**No. of dwellings**	**No. of buildings**	**No. of inhabitants**	**m² national reference area** (living space)	**m² EPISCOPE reference area**
national	38.8 million	18.2 million	75.8 million	3.54 billion	3.89 billion

The long-term German climate protection target is defined as a reduction of greenhouse gas emissions by 80 % to 95 % until 2050 related to the year 1990 [Bundesregierung 2010]. This target range is here analysed from the point of view of residential buildings. The emissions of CO_2 – the most relevant greenhouse gas – are reported. Besides the momentary emissions of the year 2050 also the cumulative emissions until 2050 are analysed compared to a target line which is defined by the intermediate national emissions reduction targets (40 % in 2020, 55 % in 2030, 70 % in 2040). In 2050 the target line is assumed to end at the mean value of the above mentioned target interval (82.5 % in 2050).

The main question to be answered by the scenarios was: How fast must changes of thermal protection and the introduction of new heating systems take place in the building stock so that it will be early enough to reach the targets?

Scenario Approach

A scenario model was developed in the Octave/Matlab environment which is to a large extent based on existing models developed in TABULA and in a national project ("Zielerreichungsszenario") [IWU 2012], [IWU 2013], so that the results can directly be compared. With the new software long-term scenarios can be calculated on an annual basis which was not possible with the old models. Calculations of space heating and final energy consumption are based on an annual / heat period energy balance method. Model results of 2009 were compared with statistical data of the building stock's energy consumption in the years before showing satisfactory compliance [IWU 2012], [IWU 2013]. Inputs to the model are detailed assumptions about future rates of thermal building modernisation and installation / replacement of heat supply systems. Also the new building sector (construction after 2009) and simplified models of district heating and general electricity generation (used for heat supply) are included.

The problem of evaluating cogeneration (CHP) systems was solved by assuming that all electricity produced by the observed CHP is used in the building sector at the same time (for electric heating and hot water supply, directly or by heat pumps). The remaining electric energy is served by the modelled mix of electric power generation systems.

The technical options considered were restricted to approved technologies of building insulation and heat supply (e.g. solar thermal systems, heat pumps, biomass- and gas-driven CHP but no deep geothermal energy, no seasonal solar heat storage). Attempt was made to carry out realistic energy balance calculations. For example it is assumed that thermal bridges and internal temperatures increase with the progress of thermal building insulation.

Data Sources

Information on the number of buildings, dwellings and the living space of the German residential building stock is based on the national census which was carried out in 2011 [SÄBL 2015]. The basic data on the state of the building stock concerning thermal protection and applied heat supply systems is provided by a representative survey of more than 7,000 residential buildings which was carried out by IWU in cooperation with chimney sweepers [IWU 2010]. In a 16 page questionnaire detailed information of the buildings was collected concerning the current state of the buildings and current trends (e.g. annual rates of thermal protection of the building elements). The survey describes the German building stock at the end of the year 2009 and it reflects average trends of the years before. So the survey is in principle out-of-date, but because no other suitable data source is available it was used as a basis for the model.

Description of the Basic Case and the Most Relevant Scenarios

According to the existing data the Basic Case and starting point of the scenario calculations is the German residential building stock in 2009. At that time modernisation progress of thermal protection was about 21 %: That means that 21 % of the thermal envelope area of the building stock (related to the area of all walls, roofs or upper floor ceilings, ground floors or cellar ceilings and windows) had already been modernised[10]. The respective area-weighted annual rate of thermal modernisation was in the magnitude of 0.8 %/yr. Concerning the modernisation of heat supply (exchange of the main heat generator) the annual rate was almost 3 %/yr. Gas or oil boilers were the most common existing heating systems in the building stock and with a fraction of 83 % they were still the most common systems among the new installed heat generators. Accordingly the fraction of “alternative” systems with lower CO_2 emissions (heat pumps, biomass systems, CHP systems – also via district heating) among the new heat generators was only about 17 %.

The definition of scenarios is based on results of an earlier project [IWU 2013] which provided a snapshot analysis of the year 2050 looking at different variants concerning the progress of thermal protection and heat supply from renewable sources. The observed variants show that the realistic potentials of energy saving must be fully used (improved insulation of about 75 % of the existing building stock or 95 % of the old building stock) and at the same time the heat supply structure must change completely to reach the CO_2 targets.

Against that background three target-oriented scenarios were defined. All of them reach an accelerated development towards energy saving and introduction of efficient and renewable heat supply which in its final state is characterised by

- an approximate doubling of the annual rate of thermal building insulation (to be interpreted as a mean value, in fact detailed assumptions distinguishing between building age classes and types of elements were underlaid)
- a complete structural change of the annually installed heating systems: The annual modernisation rate of main heat generators is in the magnitude of about 3 %/yr and does not need to be increased much. But among the new systems there must be a change away from boilers towards electric heat pumps and CHP (installed in multi-family houses or district heating networks, as far as possible driven by biomass). Apart from that, installation rates of accompanying solar systems are doubled at the same time.

But the time period which is assumed to be needed to introduce these accelerated dynamics differs between the scenarios:

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[10] In case of windows the availability of thermal protection glazing was considered.

- **Scenario "basic":** It is assumed that the increased rates of thermal modernisation and the changed heat supply structure (of new systems) are reached in a linear 10-year-development from 2015 until 2025. This scenario can be seen as ambitious but attainable.
- **Scenario "quick":** The final state (doubled rates of thermal modernisation / new structure of new heating systems) is reached already within 5 years until 2020. This scenario can be interpreted as very optimistic.
- **Scenario "slow":** The development is delayed (5 years trend scenario until 2020) and it takes longer to reach the final state (15 years from 2020 to 2035). The scenario can be seen as realistic but much less ambitious than "basic".

The development of the annual rate of thermal modernisation in the building stock 2009 (houses built until 2009) is shown in Figure 9. The rate is defined as the area of building elements (walls, roofs/upper ceilings, ground floors/cellar ceilings, windows) which is provided with improved insulation divided by the total area of those elements in the building stock 2009.

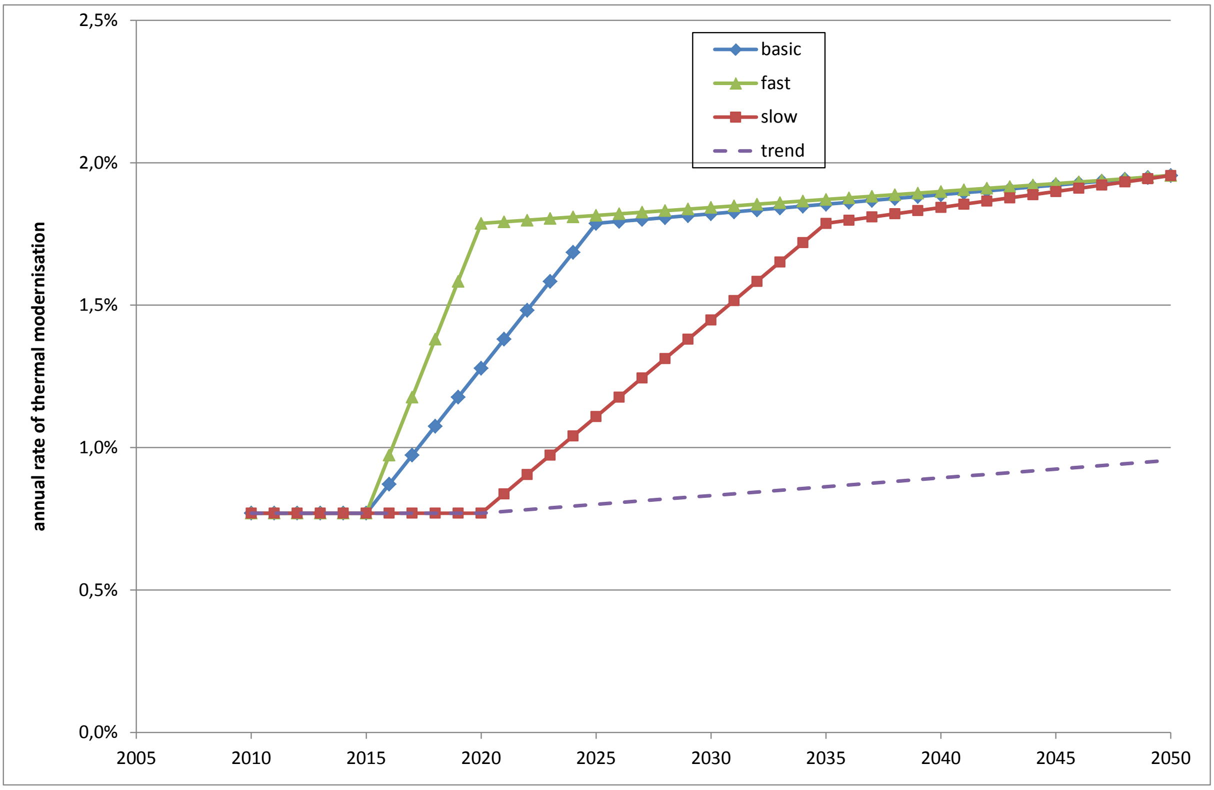


Figure 9: Development of the annual thermal modernisation rate in the German residential building stock 2009

During the same time of strong linear increase of the thermal modernisation rate also the structure of new installed heat generators changes completely until a fraction of 90 % of alternative systems (mainly heat pumps, but also CHP in the buildings or district heating, biomass boilers) is reached in 2020 ("quick"), 2025 ("basic") or 2035 ("slow").

Common to all three scenarios is the assumption that until 2020 a nearly zero energy building (NZEB) standard will be stepwise introduced in the new building sector (here oriented towards the "KfW-Effizienzhaus 40" – a German standard promoted by a KfW support programme [IWU 2014]), and that until 2050 there is a continuous change of the structure of district heating (towards efficient CHP, mainly biomass-driven) and electric power generation "for the building sector" (towards 55 % renewables, 45 % efficient natural gas power plants).

The trend scenario is widely based on the building stock modernisation trends observed 2009 by a survey, which are extrapolated until 2050 assuming only a small increase. No changes are assumed concerning the current structure of district heating and new buildings' standards (NZEB standards are not achieved), but the structural change of electric power generation is also applied to the trend approach.

Given that biomass is a renewable energy source but with very restricted potential it was assumed in all target-oriented scenarios that the total consumption in the buildings or for district heating and electricity production (used for building heat supply) should not exceed 100 billion kWh/a related to the lower calorific value (see [IWU 2013]).

Results

The total progress of thermal modernisation in the building stock 2009 (resulting from the annual rates shown above) is depicted in Figure 10. In 2050 72 % ("slow"), 77 % ("basic") or 79 % ("quick") of the building stock have been refurbished by thermal modernisation (related to the total area of thermal building envelope).

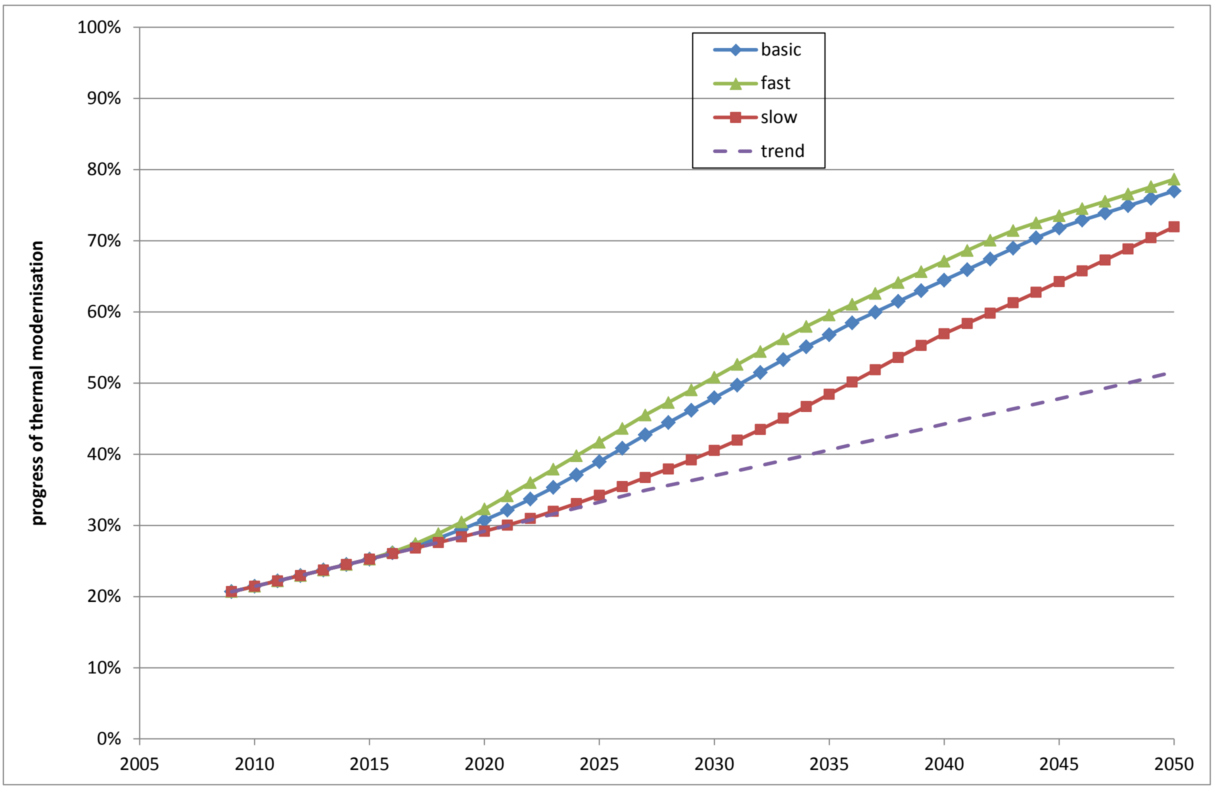


Figure 10: Progress of thermal modernisation in the German residential building stock 2009

At the same time the fraction of "alternative" heat supply systems (related to the supplied living area) increases to values between 78 % ("slow") and 88 % ("fast"). In the scenario "basic" 87 % are achieved. For that scenario in Figure 11 the split among the different heat supply systems is depicted. Electric heat pumps play a major role in 2050 with a fraction of almost 60 %.

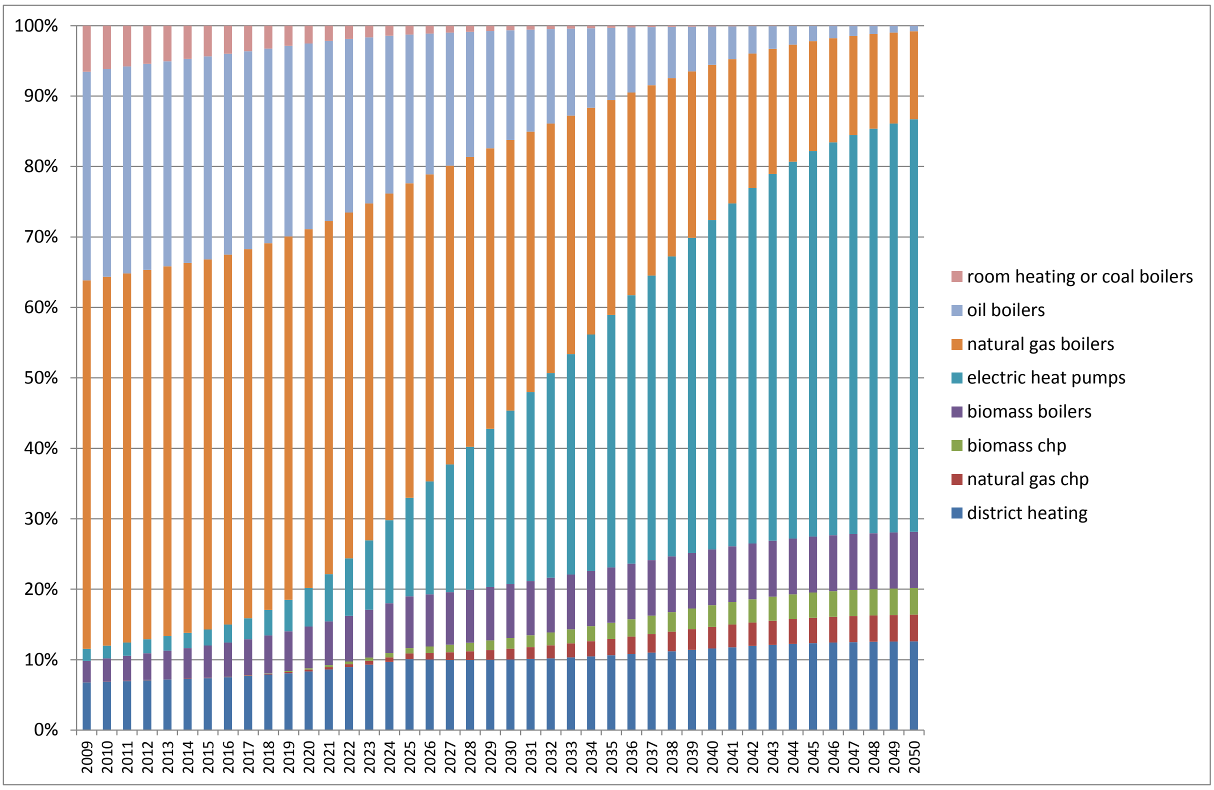


Figure 11: Fraction of heat supply systems (main heat generator) in the German residential building stock 2009 in the scenario "basic"

The main heat generators are accompanied by additional solar systems (solar thermal or combination of photovoltaics and electric heat pump) in 82 % ("slow") to 95 % ("basic / quick") of the building stock 2009. Such high fractions are possible because it was presumed that for example photovoltaic modules do not necessarily need to be installed directly at the buildings.

Figure 12 shows the development of the total CO_2 emissions in the German residential building sector for the three target-oriented scenarios and the trend scenario. The target range of the year 2050 and the target line are also shown.

The concrete numbers of CO_2 emissions and the total heat demand (related to the EPISCOPE reference area) as well as the CO_2 emission factor of heat supply are shown in the table of summary indicators (Table 13) for the scenarios "trend", "basic" and "slow". The individual benchmark is marked according to the CO_2 target line. In "basic" the area-related CO_2 emissions are reduced from 31.7 kg/m²a in 2015 to 5.8 kg/m²a in 2050 (-82 %). This is achieved by a reduction of the total heat demand from 139 kWh/m²a to 82 kWh/m²a (- 41 %) and by a reduction of the CO_2 emission factor of heat supply from 0,228 to 0,071 (- 69%). The total heat demand includes the space heating energy demand of the building stock 2009 which is decreasing by 45 % from 109 kWh/m²a in 2015 to 59 kWh/m^{2}a in 2050[11].

[11] In the national report [IWU 2015] the contribution of ventilation heat recorvery systems was considered in the heat demand numbers (total heat demand as well as space heating energy demand). Accordingly, in the national report the heat demand values are lower and the emission factors are higher than in the here presented summary indicators.

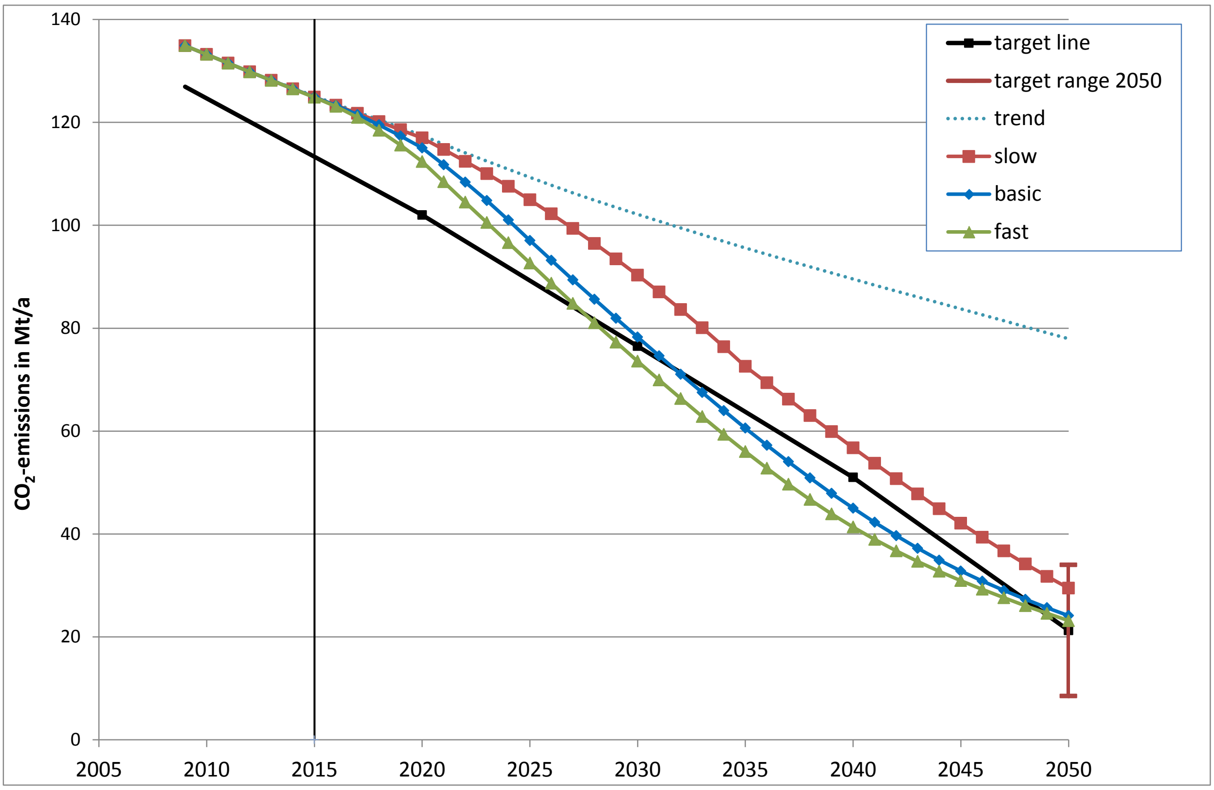


Figure 12: CO_2 emissions of heat supply (heating and hot water generation) in the German residential building stock (total emissions in all relevant sectors: buildings / district heating / electricity production) for the three target-oriented scenarios “basic”, “quick”, “slow” and the trend scenario in Mt/a (million tons per year)

For reducing the greenhouse effect not only the target 2050 but the cumulated emissions over time are relevant. They were examined for the period 2016-2050 and compared with the value of the target line (2384 Mt). The emissions of the scenarios “trend” and “slow” are clearly above the target value (46 % / 16 %). Because the target line is also exceeded in the year 2050, higher cumulated emissions in the period after 2050 would be already predetermined. The scenario “basic” is more satisfactory (exceeding the target value of cumulative emissions by only 4 %) whereas “quick” is 1 % below the target.

The focus of the scenarios was on the long-term emission reduction targets. Nevertheless it seems as if the short-term targets 2020 could not be kept at all. Such a conclusion would appear on one hand plausible because building stock modernisation is a long-term process which can hardly show short-term success. On the other hand it must be considered that a targeted analysis of measures which are effective in the short-term was not carried out, that the exact position of the actual emission level compared to the target line is uncertain (based on uncertain survey data and model assumptions) and that also weather (e. g. a couple of warm winters) might affect the short-term development of emissions. Therefore, exact conclusions about the reaching of targets in 2020 are hardly possible with the available approach.

Table 13: Summary Indicators <DE> Germany

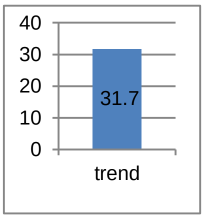
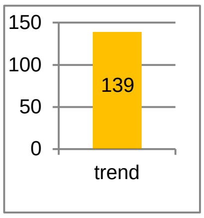
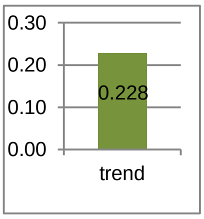
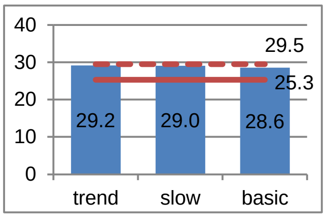
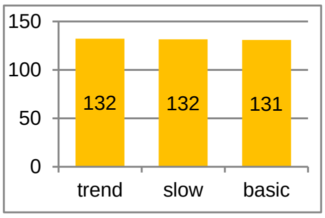
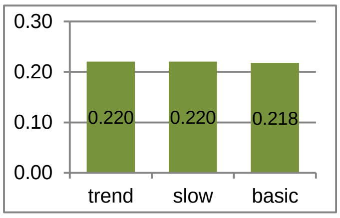
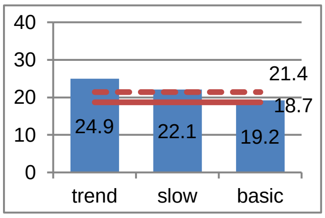
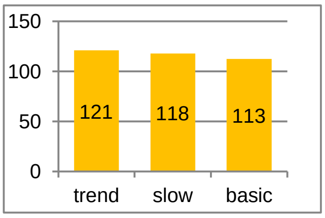
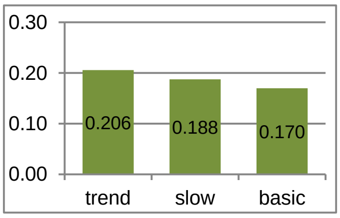
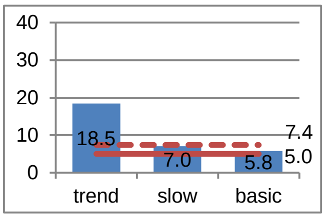
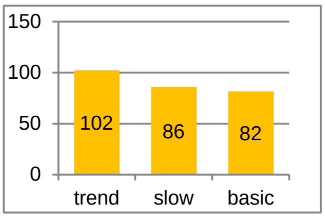
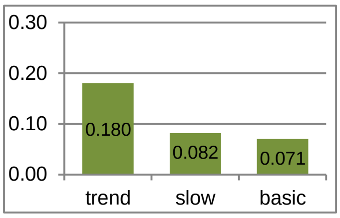
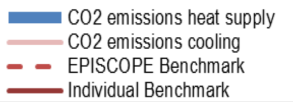
	EPISCOPE Ref. Area	CO_2 emissions	Total heat demand	CO_2 emission factor heat supply
	10^9 m²	kg/(m²yr)	kWh/(m²yr)	kg/kWh
2015	3.95			
2020	4.03			
2030	4.10			
2050	4.23			
Explanation				
		$m_{CO2,heat\ supply}$: annual carbon dioxide emissions (related to EPISCOPE reference area) $m_{CO2,heat\ supply} = q_{total} \times f_{CO2,heat\ supply}$ 	q_{total}: total heat demand (heat generation for space heating and DHW, related to EPISCOPE reference area)	$f_{CO2,heat\ supply}$: total CO_2 emission factor of heat supply
Comments				

Table 14: Final energy by fuel <DE> Germany, gross calorific value [TWh/yr]

	2015	2020			2030			2050		
Absolute figures	trend	trend	slow	basic	trend	slow	basic	trend	slow	basic
natural gas	304.6	290.0	287.4	278.8	256.9	227.6	181.1	199.8	73.6	54.1
liquid gas	small contribution, considered as natural gas									
oil	181.8	166.4	166.3	155.1	134.2	109.7	71.6	79.9	9.8	2.9
coal	1.4	0.1	0.1	0.1	0.0	0.0	0.0	0.0	0.0	0.0
wood / biomass	69.0	75.9	75.5	71.6	86.11	77.0	71.0	103.6	56.2	51.9
district heating	36.2	37.8	37.7	39.4	39.3	42.3	40.3	40.1	34.6	32.4
electric energy (used for heat supply)*	27.6	24.9	25.0	28.8	22.7	32.3	48.1	24.7	59.3	60.0

*does not include electricity which was produced by CHP systems in the residential buildings; the complete fuel demand of those CHP systems (for heat and electricity generation) is included in natural gas and biomass

Conclusions

– The trend development is missing all targets: a clear change of course will be necessary.

– The three target-oriented scenarios keep the CO_2 emission target range for 2050 “-80 % to –95 %”. But the scenario “slow” is at the upper limit and always above the target line whereas “basic” is more satisfactory, also almost keeping the 2030 target.

– Whereas the scenario “fast” might appear too optimistic the results of the scenario “basic” are also still satisfactory. This means that the doubling of thermal modernisation rates and the introduction of a new structure among the new heating systems should be reached within the next 10 years until 2025. This would lead to a path which ends in the middle of the CO_2 emission target range of 2050 and also in the time before it keeps close to the target line. Accordingly emission reduction is achieved early enough to also almost reach the assumed target of cumulative emissions.

– Exploiting all available potentials of energy saving and renewables also means that fuel consumption in summer (both of fossil fuels and of biomass with its short potential) should mostly be avoided. This is possible by an area covering supply with solar thermal systems or (e.g. if the buildings’ roofs are not suited) by heat pumps driven by photovoltaic systems (which do not need to be installed on top of the same buildings) or surplus wind energy. Also the assumed biomass potential of 100 bill kWh/yr is completely used in all three target-oriented scenarios.

– In the target-oriented scenarios electric heat pumps play a predominant role (in “basic” they contribute almost 60 % to the heat generation of the main heating systems in 2050). Accordingly, the change of electric energy generation towards a large fraction of renewables (In winter: biomass CHP, biomass power plants and wind energy. In summer: PV systems accompanying solar thermal systems) play a major role for achieving the CO_2 reduction targets.

– Also the structure of district heat generation is an important factor in the target-oriented scenarios: More than 50 % of district heating is provided by biomass, most of it by biomass-driven CHP systems which at the same time produce electricity for the above mentioned electric heat pumps.

Altogether it can be concluded that within the next 10 years (until 2025) continuous progress should be made to achieve a doubling of the annual rates of thermal building modernisation and a completely changed structure of the new installed heating systems (away from boilers to heat pumps, CHP and solar systems). In addition also the structure of district heating and electric power generation (used for heat supply e.g. by heat pumps) will play an important role to reach the long-term climate protection targets. In both sectors a continuous change towards a share of more than 50 % of renewable energy will be necessary until 2050.

Sources / References <DE> Germany

Table 15: Sources / References <DE> Germany

Reference shortcut	Concrete reference (in respective language)	Short description (in English)
[Bundesregierung 2010]	Bundesministerium für Wirtschaft und Technologie (Hrsg.) (2010): Energiekonzept für eine umweltschonende, zuverlässige und bezahlbare Energieversorgung, 28. September 2010. Avialable at: http://www.bundesregierung.de/ContentArchiv/DE/Archiv17/_Anlagen/2012/02/energiekonzept-final.pdf?__blob=publicationFile&v=5 [2015-07-29]	Energy concept of the German Government
[IWU 2010]	Diefenbach, N./Cischinsky, H./Rodenfels, M. (2010): Datenbasis Gebäudebestand – Datenerhebung zur energetischen Qualität und zu den Modernisierungstrends im deutschen Wohngebäudebestand, Institut Wohnen und Umwelt, Darmstadt. Available at: http://www.iwu.de/fileadmin/user_upload/dateien/energie/klima_altbau/Endbericht_Datenbasis.pdf [2015-07-27]	Report about a representative survey of German residential buildings
[IWU 2012]	Diefenbach, N.; Loga, T. (ed.) et al. (2012): Application of Building Typologies for Modelling the Energy Balance of the Residential Building Stock, TABULA Thematic Report No.2, Institut Wohnen und Umwelt, Darmstadt. Available at: http://episcope.eu/fileadmin/tabula/public/docs/report/TABULA_TR2_D8_NationalEnergyBalances.pdf [2015-07-29]	Report of the TABULA project team including a documentation of the German building stock modelling approach.
[IWU 2013]	Diefenbach, N./Malottki, C.v. et al. (2013): Maßnahmen zur Umsetzung der Ziele des Energiekonzepts im Gebäudebereich – Zielerreichungsszenario; BMVBS-Online-Publikation Nr. 03/2013. Available at: http://www.bbsr.bund.de/BBSR/DE/Veroeffentlichungen/BMVBS/Online/2013/DL_ON032013.pdf?__blob=publicationFile&v=5 [2015-07-27]	Report on CO_2 reduction scenarios until 2020, a snapshot analysis of 2050 and a discussion of climate protection instruments. Also including information on the applied scenario model which is the basis of the German EPISCOPE approach.
[IWU 2014]	Diefenbach, N.; Stein, B. et al. (2014): Monitoring KfW-Programme „Energieeffizient Sanieren“ und „Energieeffizient Bauen“ 2013, Institut Wohnen und Umwelt, Darmstadt. Available at: http://www.iwu.de/fileadmin/user_upload/dateien/energie/Monitoringbericht_2013_05.12.2014.pdf [2015-07-29]	Current annual monitoring report on the KfW support programmes for energy efficiency measures in existing and new residential buildings
[IWU 2015]	Diefenbach, N.; Loga, T.; Stein, B. (2015): Szenarienanalysen und Monitoringkonzepte im Hinblick auf die langfristigen Klimaschutzziele im deutschen Wohngebäudebestand, Institut Wohnen und Umwelt, Darmstadt. Available at: http://episcope.eu/fileadmin/episcope/public/docs/pilot_actions/DE_EPISCOPE_NationalCase_Study_IWU.pdf [2015-10-19]	Detailed Report of the German EPISCOPE subproject
[SÄBL 2015]	Statistische Ämter des Bundes und der Länder (2015): Ergebnisse des Zensus 2011 zum Berichtszeitpunkt 9. Mai 2011, siehe: https://www.zensus2011.de [2015-07-27]	The national census was carried out in 2011. Simple analysis can be carried out on the website, requests of more complex analysis can be sent to the statistical offices of the German federal state and the lands.

3.3 <ES> Spain

Residential Multi-family houses built between 1940 and 1980 in the Regional Residential Building Stock of the Comunitat Valenciana

(by EPISCOPE partner IVE)

Observed Building Stock and Aims of the Scenario Analysis

The observed building stock consists, mainly, of the following: single family detached house, terraced house, multifamily housing and apartment buildings. These are then divided into different periods of construction time: prior to 1900, 1901-1936, 1937-1959, 1960-1979, 1980-2006 and 2006-onwards.

The main target of the pilot action is to study and analyze the potential for energy savings and emissions reduction that the residential building stock in the Comunitat Valenciana encloses. There are no particular climate protection targets apart from those derived from EU 20-20-20 Directive (reduce greenhouse gas emissions by at least 20 %, increase the share of renewables in final energy consumption to 20 % and a 20 % increase in energy efficiency by 2020) [EC 2007]. Therefore, the applicable legislation for the achievement of EU's targets are the National Plan for renewable Energies [MFOM 2011] and The National Action Plan for Energy Efficiency [MFOM 2010], whose objectives are reducing 26.4 % of primary energy consumption at 2020 and increasing different quantities of generated energy from renewable sources during this periods of time.

Considering the construction features and state of conservation, this pilot action is focused on multi-family residential buildings, designed mainly to primary residences, built between 1940 and 1980 which represent the greatest potential for energy savings due the lack of technical standards in the energy efficiency field in the construction period and the low investment in conservation and maintenance carried out during their service life. Indeed, the buildings built in this period represent about 50 % of the housing stock.

Nationally, there is a requirement which implies that all buildings that were 50 years or older as of the 28th of July 2013 should be evaluated in terms of physical state, accesses and energy consumption. This is called the 'Informe de Evaluación del Edificio' (Report on the Building Evaluation), and all the building stock should have it completed on the 28th of July 2018 [MFOM 2013].

Table 16: Scope of the observed building stock in <ES> Spain, Multi-family houses built between 1940 and 1980 in the regional residential building stock of the Comunitat Valenciana
[INE 2001], [IVE 2015]

Scale	No. of dwellings	No. of buildings	No. of inhabitants	m² national reference area*	m² EPISCOPE reference area
Regional	692,641	47,984	1,385,282	58.9×10^6	64.8×10^6

* Note: m^2 national reference data obtained by multiplying 85.02 m^2, which is the average conditioned floor area for this type of dwelling, by the number (692,641) of dwellings (data from [IVE 2015]). m^2 EPISCOPE reference area obtained by the conversion factors described in [IWU 2013].

Scenario Approach

Methodical approach:

1. Characterization of residential building stock
2. Modelling building stock (comfort conditions)
3. Real consumption of housing stock in the Comunitat Valenciana (Valencia Energy Agency) [IVACE-AVEN 2013]
4. Comparison of actual consumption with theoretical consumption (comfort conditions)
5. Development of user surveys and building audits for data checking
6. Improvement measures
7. Possible scenarios

Data Sources

- Data and published studies on energy consumption in the residential sector as are the works produced by the Institute for Diversification and Energy Saving (IDAE) [IDEA 2011], the Census of Population and Housing 2001 of the National Statistics Institute (INE) [INE 2001] and the RehEnergía project by Cerdá Institute [Instituto Cerdá 2008].
- Reports on energy produced by the Valencian Energy Agency (AVEN) [IVACE-AVEN 2013], Information collected through user surveys and meetings with industry representatives and Information-made by energy demand studies (CERMA tool) [IVE 2011], exploiting the results of the surveys, characterization and evaluation of solutions, cost estimation, etc.

Description of the Basic Case and the Most Relevant Scenarios

First, the segment of the building stock on which scenarios should be applied was selected, concluding it would be multi-family buildings built during the period 1940-1980 (which is approximately half of the buildings built during this period). In addition, three improvement measures were considered for all scenarios: improving the façades, windows, roofs and/or a combination of them. These passive measures were selected as they are the improvements that last longer, and that require much less maintenance than systems. In economic terms, an analysis was made supposing an investment grant of 50 % of the final cost of the different scenarios. These amounts were proposed bearing in mind that current policies, like the PAREER plan [IDAE 2015], may develop for these renovation proposals so it is a realistic approach.

Improvements in façades, roofs and windows were proposed taking into account the data of the energy consumption per type of building and the U-values of the most representative construction elements. Then, the impact of undertaking the measures proposed was calculated: decrease of energy consumption due to a reduction in the U-values mainly, plus a reduction in CO_2 emissions due to decreasing energy consumption. Trend scenario consists of the building stock included in this study, taking no action on it.

In order to establish the weight of the three improvements named on the scenarios, how much energy is saved by applying them individually was calculated. It was proved that modifications on the façade saved double than changing the windows, and three times more than modifying the roofs. Hence, more weight was given to the facades. The weight distribution among the proposed measures is as follows:

Table 17: Type of improvements on existing buildings

Constructive elements	Improvement	Distribution of improvements (%)
Façades	Insulation (external façade)	30
	Insulation (internal façade)	30
Rooftops	Insulation	10
Windows	Double glass windows	30

This distribution was considered for all the scenarios; the difference among them depends on the amount of buildings that are modified.

In order to carry out the calculations regarding the relationship between scenarios, an Excel spreadsheet was developed where it is possible to introduce different variables that may change the energy saving options (only acting on façades, combination of two or more solutions, etc.). So, although we considered the distribution described above, other options could be explored in the future.

Given all the information discussed above, 6 possible scenarios were calculated between the years 2012 and 2021. In the first of them, a renovation of 10 % of the existing building stock was supposed over a 10 year period, in the second, 20 %, and 30 %, 40 %, 50 % and 80 % for the rest.

The three most relevant scenarios are the 30, 40 and 50 % ones, because the three reduce considerably the energy consumption and are feasible in manpower terms. Scenario 6, with 80 % of the building stock improved, is far too away from the current rates, and both scenarios 1 and 2, are far away from the reduction targets.

Results

For achieving a significant reduction in final energy consumption (greater than 20 % energy saving) for the year 2021, 80 % or more of the building stock should be renewed during the period 2012-2021 (Scenario 6). This would be more than 55,000 building renewals per year, which is a far great rate of current renewal and quite difficult to accomplish. The investment for this scenario is 1,406 million €. A more plausible scenario is number 4, which includes the renewal of 40 % of the considered building stock, with a renewal rate of 27,000 buildings per year and energy savings of about 10 %. This would cost around 703 million €. Scenario 1 would suppose the intervention on only 10 % of the existing stock, with an annual rate in compliance with those suggested in the last Housing plan, of 6,925 yearly renewals. On the other hand, this scenario would only reduce energy consumption in 2 %, which is quite an irrelevant quantity. So, with this rate, we can conclude that the national target of inspecting all the buildings which are 50 or more years old by the end of 2018 will not be accomplished.

These improvements are directed towards the fulfilment of the CTE (Código Técnico de la Edificación, Spanish legislation for buildings) [MFOM 2009], in which the new U-values after renewals on façades, windows and/or roofts have to achieve established standards. The renovation is focused on the façades as it’s the most efficient element in energy reduction standards.

Another option that may achieve similar savings whilst intervening in a lower percentage of the building stock would be to propose stricter improvements than those required by the CTE and closer to the NZEB approach, prioritizing renewals that improve insulation at the building envelope. Once this renewal is managed, we could propose the improvement of systems, adding renewable energy sources, although this would obviously increase the investment.

It also has to be noted that real energy consumption data have been considered, not using data obtained from energy evaluation programs that consider much higher consumptions. This has been detected up to 60% of cases. The use of theoretical data from energy evaluation programs would result in much higher energy consumption reduction, however, it wouldn't be suitable for realistic scenarios.

Table 18: Proposed scenarios and its main features [IVE 2015]

Intervention on building stock	Possible scenarios					
	S1	**S2**	**S3**	**S4**	**S5**	**S6**
Characteristics of the renewed building stock						
Building stock (during the period 1940-80) intervened	**10 %**	**20 %**	**30 %**	**40 %**	**50 %**	**80 %**
Number of renewed buildings at 2021	69,254	138,518	207,782	277,048	346,308	554,105
Number or renewed buildings per year, up to 2021	6,925	13,852	20,778	27,705	34,631	55,411
Savings and reductions						
Energy savings after 10 years	2 %	5 %	7 %	10 %	12 %	20 %
Energy reduction, 2012-2012 (MWh)	247,871	495,969	744,016	992,143	1,240,259	1,984,494
Reduction in CO_2 emissions 2012-2021 (T)	54,804	109,660	164,504	219,367	274,227	438,782
Cost savings after 10 years (m €)	62	124	186	248	310	495
Cost savings after 20 years (m €)	143	286	429	571	714	1,143
Cost savings after 30 years (m €)	224	448	671	895	1,119	1,790
Costs and investment grants						
Building budget (m €)	201	403	604	806	1007	1612
Total investment budget (m €)	244	488	731	975	1219	1950
Investment grant (50%) (m €)	122	244	366	488	609	975
Private investment cost (m €)	122	244	366	488	609	975
CO_2 emissions return (m €)	1	1	2	2	3	5
Number of jobs created at 2021	5,368	10,736	16,082	21,450	26,818	42,900

Table 19: Summary Indicators <ES> Spain

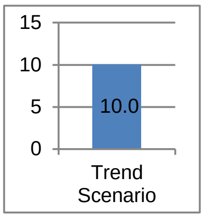
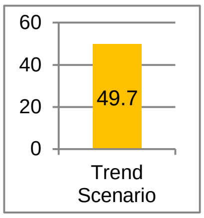
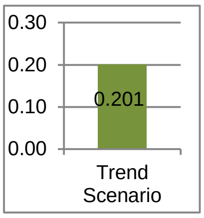
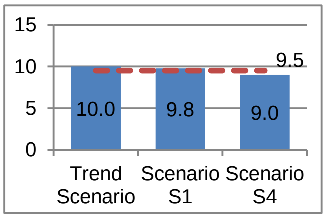
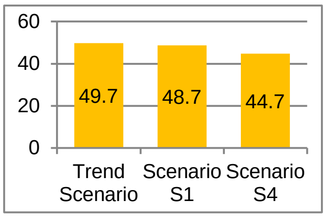
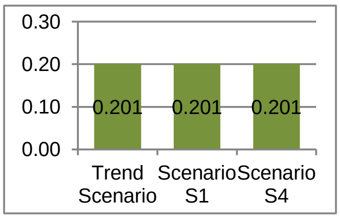
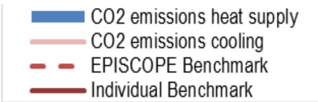
	EPISCOPE Ref. Area	CO_2 emissions	Total heat demand	CO_2 emission factor heat supply
	10^6 m²	kg/(m²yr)	kWh/(m²yr)	kg/kWh
2015	64.8			
2020	64.8			
2030				
2050				
Explanation				
		$m_{CO2,heat\ supply}$: annual carbon dioxide emissions (related to EPISCOPE reference area) $m_{CO2,heat\ supply} = q_{total} \times f_{CO2,heat\ supply}$ 	q_{total}: total heat demand (heat generation for space heating and DHW, related to EPISCOPE reference area)	$f_{CO2,heat\ supply}$: total CO_2 emission factor of heat supply
Comments				
There is no data for 2030 and 2050, as our plan analysed the period 2012-2021. Reference area obtained by considering 85.02 m², average, of each dwelling in the considered building stock. This area is that to be conditioned, so we multiplied it by the number of dwellings (692.641), giving 5.89 * 10^7 square metres. As conversion rates for the EPISCOPE reference area is 1:1 for this area [IWU 2013].				

Table 20: Final energy by fuel <ES> Spain, gross calorific value [GWh/yr]

	2015	2020			2030			2050		
Absolute figures	Trend Scenario	Trend Scenario	Scenario S1	Scenario S4	Trend Scenario	Scenario B	Scenario C	Trend Scenario	Scenario B	Scenario C
natural gas	590	590	578	531						
liquid gas	649	649	636	584						
oil	45	45	44	41						
coal	-	-	-	-						
wood / biomass	-	-	-	-						
district heating	-	-	-	-						
electric energy (used for heat supply)	1,356	1,356	1,329	1,220						

Note: The data for trend scenario 2015 was obtained from INE databases [INE 2001], [IDAE 2011],[IVACE-AVEN 2013],[IVE 2015], and we considered electricity used for heating. This data can be consulted on [IVE 2015], pages 32 for demand, and 71 for emissions. Scenarios S1, S4 were simulated for achieving 2 and 10 % reduction, respectively, and we applied these coefficients to obtain the estimation for final energy by fuel in these scenarios.

Conclusions

Improvements on the insulation of façades, roofs and windows were proposed as during the period 1940-1980 there was not any legislation regarding this subject and so there is no insulation on the building envelope of those buildings. Taking this into account, passive solutions were chosen as the most suitable and feasible for this building stock, rather than implementing renewable energies.

It has been concluded that the natural process for the approach on the reduction of energy consumption is, for these buildings, the application of passive measures which are widely described in the report "Estudio del Potencial de ahorro energético y reducción de emisiones de CO2 en la Comunitat Valenciana" [IVE 2015].

With the described improvements, national legislation requirements are achieved. Regarding reduction of 20 % emissions, the objective is somehow unrealistic, as acting on this stock, we should restore 80 % of it, which is quite difficult. Perhaps another approach could be combining the energy retrofitting of some of the buildings whilst improving a certain percentage of buildings with NZEB objectives.

Furthermore, heat could be supplied (at least up to certain percentage), by renewable energy technology (such as solar thermal), in new buildings (which is mandatory in Spain).

Regarding classic systems in older buildings, a solution for improvement could be to establish a similar program to that of the evaluation of buildings 50 years old commented previously, and so to encourage users to renew their old boiler installing high efficiency ones. This kind of boilers use NG instead of Gasoil or Butane gas, which combined with solar thermal systems can reduce consumption in this area significantly.

Sources / References <ES> Spain

Table 21: Sources / References <ES> Spain

Reference shortcut	Concrete reference (in respective language)	Short description (in English)
[EC 2007]	Commission of the European Communities (2007): Communication from the Commission to the council, the European parliament, the European economic and social committee and the committee of the retions. Limiting Golbal Climate Change to 2 degrees Celsius. The way adhed for 2020 and beyond. Available at: http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=COM:2007:0002:FIN:EN:PDF [2015-07-31]	
[IDAE 2011]	IDAE (2011): Proyecto SECH-SPECHOUSEC. Análisis del consumo energético del sector residencial en España. Informe final. Avialable at: http://www.idae.es/uploads/documentos/documentos_Informe_SPAHOUSEC_ACC_f68291a3.pdf [2015-07-28]	Final report ont the analysis Project on the energy consumption by the residential sector in Spain (report in spanish).
[IDAE 2012]	IDAE (ed.) (2012): Estudio sobre Consumo Energético del Sector Residencial en España. Madrid	Stuy on energy consumption in the Spanish residential sector
[IDAE 2015]	IDAE (2015): Programa de Ayudas para la Rehabilitación Energética de Edificios Existentes (Programa PAREER-CRECE)	National funding program for the rehabilitation of existing buildings. Conditions online: http://www.idae.es/index.php/id.858/relmenu.409/mod.pags/mem.detalle [2015-07-28]
[INE 2001]	INE, Instituto Nacional de Estadística (2001): Censo de Población y Viviendas de 2001. Avialable at: http://www.ine.es/censo2001/index.html [2015-07-28]	National Statistics Institute data on population and dwellings
[Instituto Cerdá 2008]	Instituto Cerdá (2008): Proyecto RehEnergía Rehabilitación energética de edificios de viviendas. Summary available at: http://www.fomento.gob.es/NR/rdonlyres/E211018F-40C5-411B-B2CB-EE951F97BC3A/98660/EViladomiu1.pdf [2015-07-28]	Study on the potential for energy rehabilitation in the spanish building stock
[IVACE-AVEN 2013]	IVACE-AVEN y Generalitat Valenciana (2013): Datos energéticos de la Comunitat Valenciana. Valencia	Report on the energy consumption at the Valencian Community for 2013.
[IVE 2011]	IVE (2011): CERMA (Calificación Energética Residencial Método Abreviado)	Program for the energy consumption qualification at new buildings and simulation of existing ones.
[IVE 2015]	Garcia-Prieto Ruiz, A./ Ortega Madrigal, L./ Serrano Lanzarote, B./ Soto Frances, L. (2015): Estudio del Potencial de ahorro energético y educción de emisiones de CO2 en la Comunitat Valenciana, IVE Instituto Valenciano de la Edificación, Valencia. Available at: http://episcope.eu/fileadmin/episcope/public/docs/pilot_actions/ES_EPISCOPE_RegionalCaseStudy_IVE.pdf [2015-10-19]	National Report on the Spanish EPISCOPE case study in Spanish language
[IWU 2013]	Loga, T./Diefenbach, N. (ed.) (2013): TABULA Calculation Method – Energy Use for Heating and Domestic Hot Water – Reference Calculation and Adaptation to the Typical Level of Measured Consumption, Institut Wohnen und Umwelt, Darmstadt. Available at: http://episcope.eu/fileadmin/tabula/public/docs/report/TABULA_CommonCalculationMethod.pdf [2015-06-26]	Description of the calculation method developed in the course of the IEE project TABULA
[MFOM 2009]	Ministerio de fomento (2009): Código Técnico de La Edificación – Documento Básico HE (2009).	Legal requirements for buildings, for both insulation and renewable energy aspects.

Reference shortcut	Concrete reference (in respective language)	Short description (in English)
[MFOM 2010]	Miniesterio de fomento (2010). Plan nacional de ahorro y eficiencia energética 2011-2020. http://www.idae.es/index.php/id.663/mod.pags/mem.detalle	General national action plan for energy efficiency.
[MFOM 2011]	Ministerio de fomento (2011). Plan de Acción Nacional de Energías Renovables. http://www.minetur.gob.es/energia/desarrollo/EnergiaRenovable/Paginas/paner.aspx	General national action plan for renewable energies
[MFOM 2013]	Ministerio de fomento (2013): Informe de Evaluación del Edificio. Available at: https://iee.fomento.gob.es/ [2015-07-28]	General information on the Report of Building Evaluation

3.4 <GB> England

National Residential Building Stock

(by EPISCOPE partner BRE)

Observed Building Stock and Aims of the Scenario Analysis

In 2012 the English Housing Survey showed there were 22.7 million dwellings in England, with 54 million inhabitants [DCLG 2014]. Just over half of all homes are terraced or semi detached and 81 % of all homes have central heating, the vast majority of these using mains gas. Most English housing is of brick construction (with approximately 2/3 cavity construction and 1/3 solid walls). Table 22 summarises some key features of the English housing stock.

Table 22: Scope of the observed building stock in <GB> England [DCLG, 2014]

Scale	**No. of dwellings**	**No. of buildings**	**No. of inhabitants**	**m² national reference area** (total floor area based on internal dimensions)	**m² EPISCOPE reference area**
National	~22.7 million	~21 million	~54 million	~2.10 x 10^9 m²	~2.10 x 10^9 m²

The challenge of the existing housing stock for the long term in England is to tackle the thermal efficiency of the housing stock, much of which is older and/or ‘harder to treat’, and the decarbonisation of the heating and cooling supply (as the majority of heating is by mains gas). This project is intended to highlight where the initial potential for refurbishment exists in the English housing stock, in which types of properties and which types of household. A key aim of the project is to evaluate more realistic refurbishment scenarios given the characteristics of the English housing stock. Improvements can be difficult and slow to be taken up, due to the older profile of the stock and the expense involved to the householder.

The Climate Change Act established a target for the UK to reduce its emissions by at least 80 % from 1990 levels by 2050 [HM Government 2008]. This target represents an appropriate UK contribution to global emission reductions consistent with limiting global temperature rise to as little as possible above 2°C. To ensure that regular progress is made towards this long-term target, the Act also established a system of five-yearly carbon budgets, to serve as stepping stones on the way. The first four carbon budgets, leading to 2026, have been set in law. The UK is currently in the second carbon budget period (2013-17). Meeting the fourth carbon budget (2023-27) will require that emissions be reduced by 50 % on 1990 levels in 2025.

These budgets are set as targets for emissions across all sectors as a whole, rather than for housing in particular. In practice each sector may have more or less to contribute in terms of savings toward the total budgets into the future, however for modelling purposes in this project it is assumed that housing will aim to meet the targets as given.

Scenario Approach

The modelling method undertaken is a ‘snapshot’ approach, giving final CO_2 emission figures in 2050 if all improvements specified are undertaken for each of the four scenarios specified. This gives a first estimation of how the 2050 targets could be achieved, and it is possible to estimate an indication of the type of changes to the current refurbishment trends (in type and rate) that will be needed to meet these targets (e.g. where market changes in rates and type of improvement will need to be implemented to meet these targets).

Data Sources

English housing survey data from 2012 [DCLG 2014] is used to calculate the potential for the installation of a number of energy efficiency improvements, and these improvements are applied in four scenarios, increasing in ambition from S1 (trend scenario) to S4 (a step-change from current trends). The modelling which these scenarios is based on is the BRE Domestic Energy Model (BREDEM) [Henderson & Hart 2015] and its derivative the UK Standard Assessment Procedure (SAP) [DECC/BRE, 2011]. Other factors such as population & carbon factor changes have also been taken into account (using data from UK Government trend predictions). Finally a modelled to real ratio has been calculated and applied using actual consumption data from the Energy Follow Up Survey 2011 [DECC 2014].

Description of the Basic Case and the Most Relevant Scenarios

The English Housing Survey 2012 shows us that there is currently good penetration of 'easy' fabric improvement measures such as loft insulation and double glazing and cavity wall insulation in the English housing stock. A large proportion of dwellings already have mains gas boilers. Areas where there is still significant scope for improvement are the insulation of solid walls, and the implementation of alternative technologies such as photovoltaics and solar water heating. A step-change in heating systems away from gas and towards efficient electric technology, such as heat pumps would be required from the current situation to gain the significant savings needed to meet the 2050 targets.

The specification of three scenarios, created to address the issues outlined above, are described below.

Scenarios S1 (Trend): A modest scenario, with relatively simple measures, progressing at a rate and direction within current trends. Simple measures of easy loft insulation, cavity wall insulation and boiler upgrades to existing gas boilers are installed. This scenario does not require changes to current market trends in the type or rate of measures being installed. More modest improvements in the CO_2 emissions factor for electricity are seen in this scenario, reflecting a less ambitious change to electricity production at a national level.

Scenario S3 (Insulation and electricity production): A long term scenario where heating systems are upgraded to condensing gas boilers (majority) or heat pumps (minority) depending on location, and all households are insulated to a good level (loft insulation, double glazing and wall insulation where appropriate), and alternative technologies are installed (photovoltaics and solar water heating, where appropriate for dwelling type). An improved CO_2 emissions factor for electricity is seen in this scenario, to reflect lower carbon electricity production at a national level.

Scenario S4 (Alternative Heating Pathway): A long term scenario where heating systems follow alternative trend of high levels of heat pumps (all suburban and rural dwellings), and all households are insulated to a high level, and electricity generation is included where appropriate. An improved CO_2 emissions factor for electricity is seen in this scenario, to reflect lower carbon electricity production at a national level.

Results

Total CO_2 emissions for the English residential stock in 2012 English Housing Survey data are modelled to be 124 million tonnes per year. This equates to 5,652 kg of CO_2 per household per year in England in 2012. Applying the modest S1 scenario lowered this figure by 34 % from 1990 levels. Scenario S3 which still utilise the mains gas network as the main source of heating, saves approximately 50 % from the base 1990 figure by 2050.

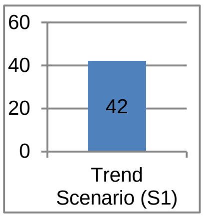
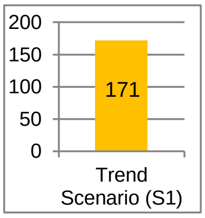
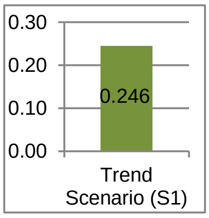
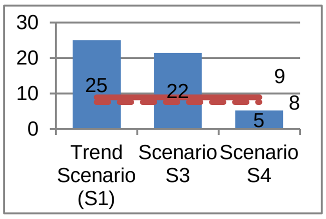
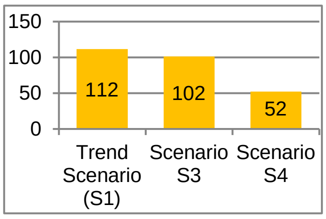
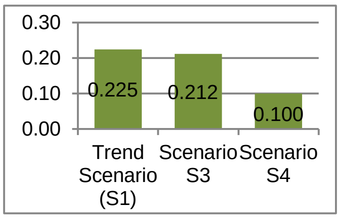
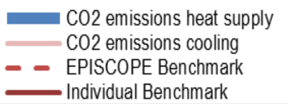
Truly deep cuts to CO_2 are only possible with the installation of large numbers of electric heat pump systems, and associated decarbonisation as seen in scenario S4. Dependence on electric heating in the form of heat pumps, coupled with significant decarbonisation of the electricity supply system, in this scenario leads to cuts of 88 %. This is the only scenario which is able to achieve the target in 2050 of reducing emissions by 80 % from 1990 levels.

Total energy use for the English residential stock is modelled to be 424.9 TWh for 2012. Applying the improvement scenarios lead to lower percentage reductions in than seen for the CO_2 emissions. S1 scenario reduced the 2012 energy use base value by 6.7 %, S3 by 25.4 % and S4 by 59.6 %.

The 2050 carbon factor applied for electricity means that the CO_2 savings for energy technologies are considerably smaller in scenarios S3 and S4 than if decarbonisation of the grid had not occurred. Savings are still seen in energy use for energy use, and thus overall power needed from power stations would be reduced which would benefit the CO_2 balance for the country when considering all sectors.

It is important to note when interpreting the scenarios that they may still overstate the actual realistic potential due to the fact that households have always upgraded to the most efficient type of system for their situation. Households may, in reality, upgrade to lower efficiency systems, insulation thicknesses etc. where regulations and circumstances allow.

Table 23: Summary Indicators <GB> England

<table>
<tr><th></th><th>EPISCOPE Ref. Area</th><th>CO_2 emissions</th><th>Total heat demand</th><th>CO_2 emission factor heat supply</th></tr>
<tr><td></td><td>10^9 m²</td><td>kg/(m²yr)</td><td>kWh/(m²yr)</td><td>kg/kWh</td></tr>
<tr><td>2012</td><td>2.10</td><td>
</td><td>
</td><td>
</td></tr>
<tr><td>2020</td><td></td><td></td><td></td><td></td></tr>
<tr><td>2030</td><td></td><td></td><td></td><td></td></tr>
<tr><td>2050</td><td>2.94</td><td>
</td><td>
</td><td>
</td></tr>
<tr><td colspan="5">Explanation</td></tr>
<tr><td></td><td></td><td>$m_{CO2,heat\ supply}$:
annual carbon dioxide emissions (related to EPISCOPE reference area)
$m_{CO2,heat\ supply} = q_{total} \times f_{CO2,heat\ supply}$

</td><td>q_{total}:
total heat demand
(heat generation for space heating and DHW, related to EPISCOPE reference area)</td><td>$f_{CO2,heat\ supply}$:
total CO_2 emission factor of heat supply</td></tr>
<tr><td colspan="5">Comments</td></tr>
<tr><td colspan="5">Trend Scenario / Scenario (S1). Observed state and trends in the English building stock in 2012.
Scenario S3. Significant improvements to building fabric and addition of alternative energy generation with heating remaining mainly from mains gas.
Scenario S4. Meeting the national targets for 2050 with large scale changes to heating and comprehensive improvements to building fabric.
All figures based on households.</td></tr>
</table>

Conclusions

The 2050 targets are only achieved in this scenario analysis by applying the S4 scenario (saving of 87 %) which requires a step change in heating systems away from mains gas to electric, along with decarbonisation of the electricity supply. These changes seem likely to require large changes in policies in order to achieve in the relatively short timescale required.

Within the English housing stock it is conceivable that it is possible to reach a near 100 % saturation level of a number of measures (e.g. loft insulation and double glazing). At the present time it is hard to understand from a practical and financial sense how successfully solid wall insulation will penetrate the market as many significant barriers to this exist. A set of scenarios have been run without solid wall insulation, and show that it is not necessarily critical to insulate solid walls to meet the 2050 targets.

Market changes will be required in the general heat supply structure. Incentives are likely to be needed to implement the required number of installations of PV, solar water heating and heat pumps required if the 2050 targets are to be met. These changes in installation rates are unlikely to happen quickly enough on their own. Heating systems are likely to naturally improve as they are relatively regularly upgraded and it is possible (and already proven) to implement legislation which requires upgrade to a minimum level (this has already been demonstrated by the successful uptake of condensing boilers over the last 10 years following legislation changes in 2005), however significant changes to the current trends will have to be applied rapidly to implement the large scale switch to heat pumps required in the relatively short timescale to 2050. Barriers to implementation of these technologies include currently the inconvenience and cost to the homeowner, along with a lack of knowledge of the technology.

Additionally a movement to lower carbon electricity generation on a national scale will be needed to reduce the current electricity carbon factor and make the installation of heat pumps worthwhile. This requires long term planning of power stations at a national level.

Further analysis could be carried out to further identify the best candidates in the national stock for refurbishment, which would help to inform the details of policies moving forward to help meet the carbon dioxide reductions required.

Sources / References <GB> England

Table 24: Sources / References <GB> England

Reference shortcut	Concrete reference (in respective language)	Short description (in English)
[DCLG 2014]	Department for Communities and Local Government (ed.) (2014): English Housing Survey: PROFILE OF ENGLISH HOUSING. Annual report on England's housing stock, 2012. Available at: https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/335753/EHS_Profile_of_English_housing_2012.pdf [2015-05-04]	EHS Profile of the English housing stock 2012
[DECC/BRE, 2011]	DECC/BRE (2011): The Standard Assessment Procedure for the Energy Rating of Dwellings (SAP). 2009 edition, v9.90. Available at: http://www.bre.co.uk/sap2009	The Standard Assessment Procedure for the Energy Rating of Dwellings (SAP). 2009 edition, v9.90.
[DECC 2014]	Department of Energy & Climate Change (ed.) (2014): Energy Follow-Up Survey (EFUS): 2011. Available at: https://www.gov.uk/government/publications/energy-follow-up-survey-efus-2011 [2015-05-04]	Energy Follow-Up Survey data analysed and written up into 11 reports
[Henderson & Hart 2015]	Henderson, John/Hart, John (2015): BREDEM 2012 – A technical description of the BRE Domestic Energy Model. 2012 Edition. Available at: http://www.bre.co.uk/filelibrary/bredem/BREDEM-2012-specification.pdf. Last updated January 2015.	BRE Domestic Energy Model. 2012 edition.
[HM Government 2008]	HM Government (2008). The Climate Change Act, 2008. Available at: http://www.legislation.gov.uk/ukpga/2008/27/pdfs/ukpga_20080027_en.pdf .	UK Government Climate Change Act 2008.

3.5 <GR> Greece

National Residential Building Stock

(by EPISCOPE partner NOA)

Observed Building Stock and Aims of the Scenario Analysis

According to national census data, the total number of conventional dwellings is 6,371,901 in 2011, 55 % of which are located in single family buildings (SFH) and the rest in apartment buildings (MFH) [ELSTAT 2015]. A mere 35 % of the total number of dwellings are empty resulting in a total of 4,111,858 inhabited dwellings in 2011. The total number of residential buildings amounts to 2,990,324, of which 62 % form the old building stock dating prior to 1980, the year that the first Hellenic building thermal insulation regulation (HBTIR) was introduced. Following EPBD transposition [Dascalaki 2012], new buildings constructed after 2011 in accordance to the new national regulation – KENAK [KENAK 2010] represent only 0.03 % of the total.

Table 25: Scope of the observed building stock in <GR> Greece [ELSTAT 2015]

Scale	No. of dwellings	No. of buildings	No. of inhabitants	m² national reference area	m² EPISCOPE reference area
National	~6.4 million (4.1 million inhabited)	~2.9 million (2.5 million inhabited)	~10.8 million	~480 x 10^6 (gross floor area) (~400 x 10^6 inhabited)	~309 x 10^6 (~250 x 10^6 inhabited)

The latest national household energy survey by ELSTAT in 3553 households [ELSTAT 2013] gives an insight of the energy-related characteristics of the building envelope and system installations. Although the heating degree-days (HDD) range from 600 in the south to over 2600 HDD in the northern parts of the country, about half of the dwellings have no kind of thermal protection, since the majority of the dwellings were built prior to 1980. Further statistical analysis of the raw data performed by NOA revealed that despite the fact that 35 % of buildings in the total residential building stock have insulated walls, only 10 % of the old building stock has upgraded the wall insulation levels to meet the requirements of HBTIR. Window replacement is among the most popular energy conservation measures (ECM). About 35 % of the old building stock has upgraded windows from single to double glazing. This reveals a very slow envelope annual modernization trend not exceeding 1 %.

Heating oil (63.8 %) remains the main fuel source for space heating, while 12.4 % uses electricity, 12 % biomass and 8.7 % natural gas. The most common heat supply systems are boilers (69 %, liquid fuels), followed by heat pumps (5 %). Other heat supply systems include direct electric (7 %), stoves (4 %) and open fireplaces (4 %). District heating is mainly in the north (climate zone D) and represents 0.73 % of the total space heating systems in the country. Electricity is mainly used for domestic hot water (62 %) followed by boilers (30 % oil, 4 % natural gas). A total of 37.6 % have solar collectors and 25.2 % use the central heating system.

A total of 59 % of the installed oil boilers are old, non-condensing and 22 % of the heat pumps are split units or systems aged over 10 years.

National targets

According to the National Energy Efficiency Action Plan (NEEAP) [CRES 2014], the new national energy savings target for 2014-2020 cumulatively amounts to ~3.33 Mtoe (38.8 Wh) or approximately 19.3 % of the total final energy consumption in 2012, with total new annual savings equal with 902.1 ktoe (10.5 TWh) in 2020. The above targets refer to all energy consuming sectors. The building sector is expected to contribute 58 % towards achieving the energy savings targets. In the residential sector, where most policy measures are applied, the accumulated energy savings for the period 2014-2020 are estimated equal to 1932 ktoe while the annual final energy savings in the year 2020 are estimated to about 523 ktoe.

The participation of renewables in the final energy consumption for heating and cooling by 2020 is specified at 20 % [N.3851/2010].

In the framework of the Hellenic pilot study, it was assumed that the targets for the CO_2 emissions reduction in the domestic sector for the years 2020 and 2030 will be equivalent to 20 % and 30 % of the respective emissions for 1990.

Table 26: National targets for the residential sector - years 2020 and 2030

NATIONAL TARGETS (RESIDENTIAL SECTOR)	2020	2030
CO_2 emissions (Mt)	5.1	3.8
Penetration of RES (in housing)	20%	31.7%
Final energy savings(*) (annual, Mtoe)	0.52	0.83
Final energy consumption (Mtoe)	3.88	2.23

(*): compared to 2012

Scenario Approach

A scenario model was developed for the assessment of the possibility of different ECMs and strategies applied in the Hellenic residential sector, towards achieving the national goals for the reduction of CO_2 emissions in 2020 and 2030. In order to take into account the differences in the availability of heat supply systems in the four climate zones of Greece (only zones B and C have a natural gas supply network and district heating is only available in zone D) but also variability of weather conditions, a total of 24 building types [Dascalaki 2011] were included in the analysis. Specifically, in each climate zone, SFH and MFH buildings were classified in three age bands according to the thermal protection regulation existing during the year of construction: pre 1980 (old building stock, no insulation), 1980-2010 (partially or fully insulated as a result of compliance with HBTIR) and post 2011 (in compliance with KENAK). In the absence of an official detailed NZEB definition at the time of this study (mid-2015), apart from the general definition in [N.4122/2013], an envisioned NZEB concept was applied for the years as of 2021 [Stein/Loga/Diefenbach et al. 2014], [Dascalaki 2014].

The model takes into account four different levels of thermal protection and three levels of modernization for the most common energy supply systems in Greece, i.e. boilers (oil, natural gas) and heat pumps. The share of other systems (direct electric, open firewood, stoves and district heating) is also considered. The distribution of envelope components and systems in the different levels was derived after a detailed statistical analysis performed by NOA using recent raw national survey data [ELSTAT 2013].

The starting reference period that defines a coherent building stock model is set at and compared with a base year of 2012 (current state). The evolution of the building stock over the years takes into account annual demolition and construction rates, as well as different modernization rates for the different envelope components, heat supply systems (gross modernization), switch to different energy carriers (net modernization), and addition of solar systems for DHW and space heating. Different inputs can be used to reflect the state and trends for each of the 24 building types included in the model.

The annual total energy demand, final energy consumption and CO_2 emissions are calculated using the national EPC tool (TEE-KENAK), for each year over the 2012-2030 period. In order to close the gap between actual vs calculated final and primary energy use and CO_2

emissions, NOA analysed raw data from about 12,000 Hellenic dwellings available from the national EPC registry [buildingcert]. The analysis was performed for the 24 building typologies to derive empirical adaptation factors f_1*(actual/calculated*) using the raw data (f_1*) and filtered data (f_1**). The average ratios based on the raw data (f_1*) range from 0.90 for SFH to 1.42 for MFH, and with the screened data (f_1**) they range from 0.54 for SFH to 0.57 for MFH (i.e. 46 % or 43 % lower actual energy consumption than calculated). These factors are used as multipliers for correcting the calculated values to obtain more realistic actual energy use. An upper bound is obtained using f_1* and an average bound using f_1** for approaching the general trend of actual energy use.

EPISCOPE field audits in over 80 refurbished dwellings (representative of building typologies) were performed by NOA for collecting data on the actual energy use "before" and "after" the implementation of popular ECMs. In addition, EPISCOPE field surveys of homeowners reaching out to over 200 dwellings (including various typologies, SFH and MFH, pre- and post-1980) provided additional data on common ECMs and current behavioural changes and trends in the use and operation of heating systems. The information was used to derive similar empirical adaptation factors (f_2) for adjusting the calculated values to account for deviations from the standard conditions of the calculations (e.g. limit hours of operation and heated floor areas, lower indoor thermostats), based on recent behavioural changes. The f_2 averages about 0.32 and is considered a lower bound (i.e. a conservative estimate of actual energy use). Details on the approach, analysis and the numerical values of all adaptation factors used in the Hellenic building stock model are available in [Dascalaki 2016] and [Balaras 2016].

The performance of each investigated scenario is assessed by comparing results against the national targets. In the framework of this pilot study, the comparison is restricted to the CO_2 emission targets.

Data Sources

Main data sources on the Hellenic building stock and energy consumption originated from the Hellenic Statistical Authority (ELSTAT), Eurostat and the official national EPC registry [buildingcert]. The main goal was to make an in-depth analysis and combine data to derive the floor areas of the Hellenic typologies. The quantitative description of the building stock quality regarding the energy-related characteristics of the building envelope and system installations was based on a statistical analysis performed by NOA using raw data from a national survey on the "Energy consumption of Households" conducted by ELSTAT during the period of 2011-2012 in 3553 households [ELSTAT 2013].

The EPISCOPE field audits and surveys provided additional information on the actual energy consumption data before vs after the implementation of ECMs and current operational characteristics. The data were used to derive empirical adaptation factors in order to make more realistic estimates of the calculated primary energy use or anticipated savings as a result of large scale implementation of ECMs in the building stock. Similar adaptation factors were also derived for adjusting calculated values in order to account for deviations from the standard calculation conditions using data on actual energy use from the official EPC registry [buildingcert 2014].

Description of the Basic Case and the Most Relevant Scenarios

The year 2012 is used as a **base case** for setting up the model. In order to derive the state indicators for 2012, NOA performed a statistical analysis of the raw data from the national survey [ELSTAT 2013]. Accordingly, thermal insulation levels vary among the different envelope components. Specifically, non-insulated components include 63.5 % of the walls and 62 % of the roofs in the whole building stock, while single glazings correspond to 55 % of the windows. Additionally, 9 % of the walls, 22 % of the roofs and 31 % of the windows of the ‘old’ building stock (built before 1980) have undergone refurbishment to upgrade insulation levels in accordance to the requiremens of HBTIR.

The main heat generators in the Hellenic building stock consume 71 % oil/gas (boilers), 17 % firewood (open fire), 11 % electricity (split units, heat pumps, direct electricity, stoves) and 0.49 % derived heat (district heating). Old heating systems are used in 74 % of the total and 78 % of the “old” building stock. Specifically, old (non-condensing) oil boilers heat 60 % of the total building stock, while the vast majority of heat pumps and split units used as the main heat generating system are over 20 years old.

The official national software TEE-KENAK was used in order to calculate the final energy consumption and CO_2 emissions for the base year. Table 27 summarises the results along with the corresponding officially reported values [EU 2014.v3].

Table 27: Comparison of calculated vs officially reported [EU 2014.v3] CO_2 emissions and final energy consumption from space and DHW heating in the residential sector (year 2012)

	EUROSTAT	Building stock model (adapted)			
		f_1*	f_1**	f_2	(f_1**, f_2)$_{average}$
CO_2 emissions (Mt)	9.4	21.9	11.4	6.3	8.9
Final energy consumption (ktoe, space heating&DHW)	3,381	8,170	4,534	2,258	3,396

The observed differences between the calculated and officially reported values indicate that the latter lie between the model calculations corrected with the adaptation factors f_1** and f_2. This is anticipated by the fact that f_1** reflects the average bound in the general trend of actual energy use, while the f_1* adapted energy consumption values can be considered as an upper bound reflecting the occupant behavioural changes as the country moves out of recession. On the other hand, f_2 reflects recent behavioural changes under the adverse economic conditions and the recession in Greece; therefore, the estimated actual energy consumption may be considered as a lower bound (using f_2), reflecting a conservative estimate of actual energy use in existing dwellings, as a result of occupant’s efforts to cut-down heating energy costs.

The average values of the calculations using f_1** and f_2 indicated as (f_1**,f_2)$_{average}$ are closer to the officially reported values and are deemed more representative of the current situation in Greece as well as for the general trend towards 2020 and onwards throughout the recession period. The results discussed hereafter correspond to this average adaptation.

A **trend scenario** was studied in order to assess the possibility to achieve the national CO_2 emission reduction targets in 2020 and 2030 keeping the envelope and system modernization trends that are observed in the building stock of 2012. An exhaustive search in published data did not reveal any official reports on modernization trends in the residential building stock. Consequently, the model was fed with values, which, for the trend scenario were carefully specified to reflect the prevailing trends in the Hellenic market and in occupants’ priorities regarding building refurbishment over the recent years collected during the EPISCOPE surveys. Accordingly, the envelope modernization rate is very low (0.6 %), involving lower values for wall insulation upgrade (0.1 %) and higher values for window replacement with double glazings (1.0 %). Similarly, the system modernization rates are also very low (0.6 %) involving the replacement of old systems with new of the same fuel and the fuel change from oil to natural gas or electricity. Both envelope and system modernization implies an upgrade to KENAK standards (regulation requirements in 2012).

Two additional scenarios (Figure 13) were considered and assessed. Specifically:

Scenario B involves moderate modernization rates (3.1 %) for the envelope components, with a higher rate for window replacement (4.6 %) and a lower one (1.9 %) for wall insulation. System modernization rates are higher than the trend scenario (1.26 %), involving the upgrade of old oil and electricity systems to new ones with higher efficiency. A faster system modernization trend (2.26 %) is applied until 2020, followed by a slow trend (0.46 %) till 2030. Fuel change trends are kept at the rates of 2012. Until 2020, the envelope and systems are upgraded to KENAK standards, while even higher efficiency system upgrades and increased insulation levels are considered for the years after 2020. A significant increase in the penetration of solar systems for DHW preparation is also considered.

Scenario C involves intensive envelope modernization with moderate rates (3.6 %) for the different components and moderate (1.13 %) upgrade of systems (i.e. high fuel change rates for old systems, in all climate zones, promoting the transition from oil to natural gas in climate zones B&C and to electricity in zone A. Replacement of old systems with new of the same fuel is kept at the rates of 2012. Increased penetration of solar systems for DHW preparation and solar heating is considered in all system modernizations before and after 2020.

The above mentioned refurbishment rates are average and refer to number of buildings of the total building stock.

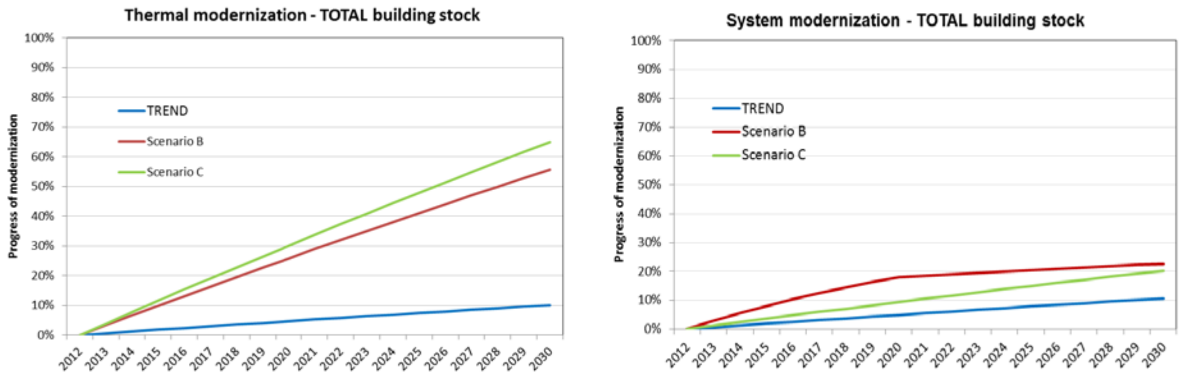


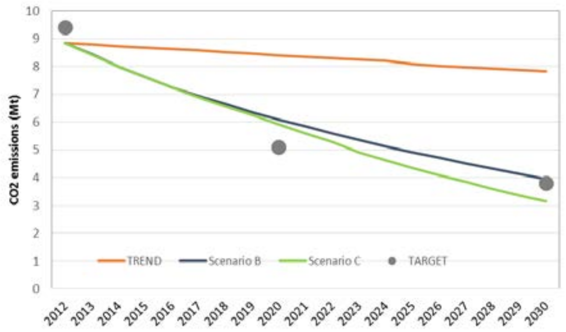
Figure 13: Envelope (left) and system (right) modernization trends in the studied scenarios.

All three scenarios have the following considerations in common:

- Envelope modernization is applied to level “0” (non-insulated) and level “1” (insufficiently insulated in accordance to HBTIR) envelope components.
- Floors are not modernized.
- In scenarios B and C both envelope and system upgrades are up to KENAK standards until 2020, while even higher efficiency system upgrades (level2) and increased insulation levels (level3) are considered for the years after in line with the envisioned NZEBs.
- System modernization is applied to level “0” systems including aged non-condensing oil boilers, split units and heat pumps.
- Only central systems using oil or electricity are modernized.
- Fuel change from oil to natural gas is considered only in climate zones B & C, where the main distribution network is available.
- District heating is considered only in climate zone D.
- The system modernization scheme does not include stoves, direct electric or open firewood systems.

Results

Figure 14 illustrates the results from the three scenarios on the annual evolution of the CO_2 emissions in the period 2012-2030. As expected, the trend scenario, with very low modernization trends, does not meet the national targets until 2030. Scenarios B and C fail to meet the national target of 2020, but are successful in reaching the target towards 2030.



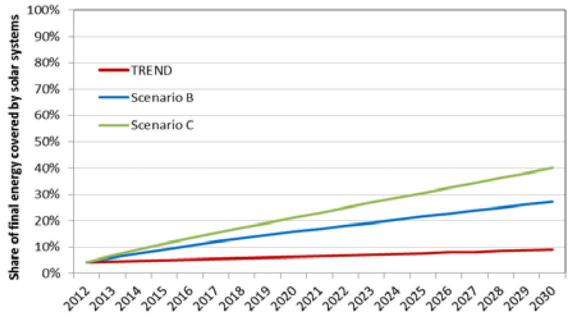


Figure 14: Evolution of CO_2 emissions (left) and share of final energy covered by solar systems for the three scenarios.

Both scenarios B and C lead to envelope modernization of 55 % and 65 % of the total building stock in a total of 18 years. Despite the fact that modernization of systems in scenario B evolves faster than in scenario C for the period until 2020, they both lead to a system modernization that barely exceeds 20 % of the systems in the total building stock by 2030. The main difference between the two scenarios lies in the quality of system modernization. Scenario C promotes the exploitation of solar energy for DHW and solar heating covering 40 % of the final energy and the use of a low carbon fuel, natural gas, to cover a significant part of the energy demand. As a result, scenario C meets the national target of 2030. Figure 15 illustrates the evolution of the three most common energy carriers used in central heat supply systems in the old (pre 1980) Hellenic residential building stock derived by scenario C.

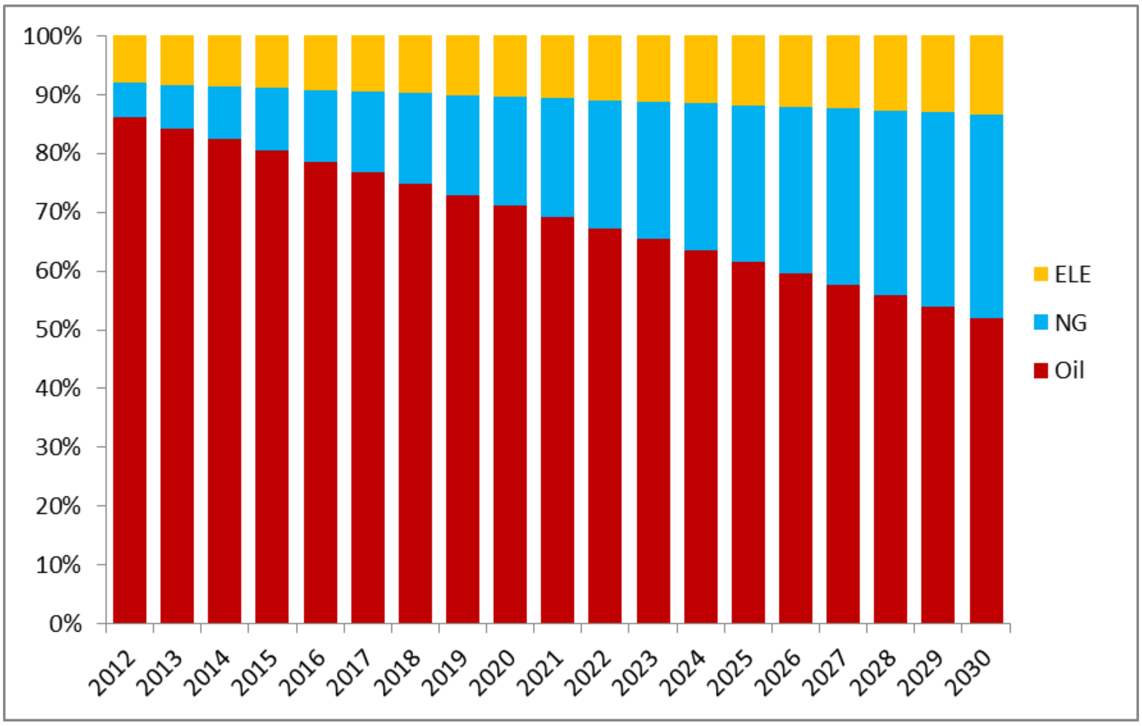
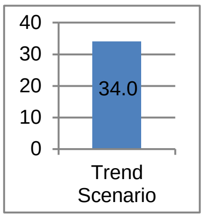
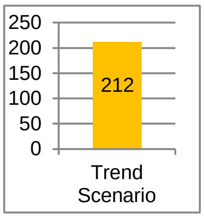
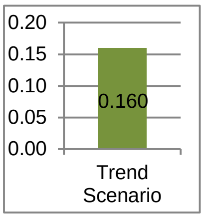
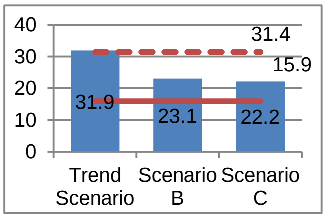
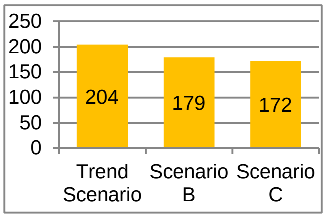
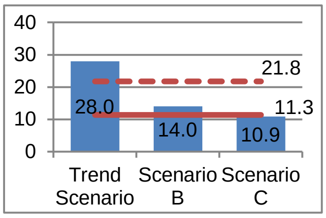
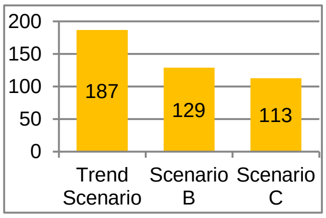
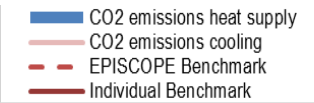


Figure 15: Evolution of energy carriers (ELE: electricity, NG: Natural gas, Oil: Heating oil) in the old (pre 1980) Hellenic building stock according to scenario C (firewood and derived heat not included).

Table 28: Summary Indicators <GR> Greece

	EPISCOPE Ref. Area	CO_2 emissions	Total heat demand	CO_2 emission factor heat supply
	10^9 m²	kg/(m²yr)	kWh/(m²yr)	kg/kWh
2015	0.26			
2020	0.26			
2030	0.28			
2050				
Explanation				
		$m_{CO2,heat\ supply}$: annual carbon dioxide emissions (related to EPISCOPE reference area) $m_{CO2,heat\ supply} = q_{total} \times f_{CO2,heat\ supply}$ 	q_{total}: total heat demand (heat generation for space heating and DHW, related to EPISCOPE reference area)	$f_{CO2,heat\ supply}$: total CO_2 emission factor of heat supply
Comments				

Trend Scenario: observed state and trends in the national building stock in 2012

Scenario B: Moderate thermal modernisation, moderate modernisation of boilers and heat pumps, faster until 2020, increase of solar installations for DHW

Scenario C: Intensive thermal modernisation, moderate modernisation of boilers and heat pumps, promotion of fuel change (from oil to natural gas in zones B and C, heat pumps in zone A and district heating in zone D), increase of solar installations for DHW and solar heating

Table 29: Final energy by fuel <GR> Greece, gross calorific value [GWh/yr]

	2012	2015	2020			2030			2050		
Absolute figures	Basic case	Trend Scenario	Trend Scenario	Scenario B	Scenario C	Trend Scenario	Scenario B	Scenario C			
natural gas	1415	1681	2111	1793	2086	2871	1728	1722			
liquid gas		0	0	0	0	0	0	0			
oil	21269	20505	19232	15287	14110	16595	9888	6707			
coal		0	0	0	0	0	0	0			
wood / biomass	12936	12712	12353	10672	9964	11630	7378	5777			
district heating	210	212	216	186	301	221	138	283			
electric energy (used for heat supply)	3652	3620	3580	2156	2168	3529	1258	1167			

Conclusions

Based on the results from this pilot study, the 2030 target for CO_2 emissions is reached by applying the scenario C that has a refurbishment rate of 3.6 % for thermal improvement of the envelope and 1.15 % for improvement of the systems' efficiency to minimize heat demand and promotes the use of solar energy systems for DHW and solar heating together with a gradual fuel change from oil to natural gas. As a result, in the end of the period 2012-2030 solar systems cover 40 % of the final energy in 2030 and the share of natural gas in the mix of energy carriers covering the remaining heating energy demand is double the current value.

Key to the future success is the minimization of heating demand, use of high efficiency equipment and systems, coupled with central solar assisted systems and potentially solar thermal assisted cooling or PV driven heat pumps. To lower the CO_2 emissions it is necessary to switch from oil burning technologies towards natural gas and electricity. However, turning to electricity for heating, needs to advance with caution in order to minimize a negative impact on power capacity of the grid, especially in the islands served by limited autonomous power plants.

Given the fact that this study did not look into decarbonisation of central power generation, on-site or nearby building green power generation (e.g. PV or CHP) additional savings could be achieved as a result of lower emissions for electricity use.

Reaching the 2020 target while securing proper indoor environmental quality, will need aggressive refurbishment rates that may be difficult to implement, given the unprecedented economic crisis and continuing recession in Greece. The current dropping trend of energy use is evident but as a result of the efforts by people to cut-down heating energy costs. Higher energy prices (e.g. imposing a fuel tax on heating oil in 2012) significantly decreased oil consumption in the residential sector by 70 %. Side effects resulted to poor indoor thermal conditions and unprecedented environmental impacts in major urban cities as a result of using open fireplaces and burning improper solid fuels. However, given the recent trends and staggering drop in use of conventional energy carriers for space heating due to family budget constraints, it may be possible to actually surpass the 2020 target as the economy continues to slow down.

As a result of the economic recession in Greece, new construction (e.g. energy efficient buildings according to KENAK) and relevant activities have plunged. The only shining star since 2011 is a set of financial incentives, with co-financing from the EU, for the implementation of ECMs in residential buildings, via the "Energy Efficiency at Household Buildings" (Exoikonomo) program. Another program on the installation of PVs on residential building roofs has boosted the installation of about 45,000 grid-connected PVs up to 10 kWp in the mainland and up to 5 kWp in the islands. However, interest in new installations dropped as a result of the "new deal" for feed-in-tariff cuts and the imposition of a retroactive levy. Undoubtedly, there is a need to continue and strengthen the applicability of financing programs, with emphasis on the use of products that will result to significant energy savings, have a good return to the homeowner, the national industry and local economy. Moreover, it is necessary to maintain stable, long term and efficient regulatory and legislative framework.

The pilot project stumbled on a number of inherent and practical problems that need to be resolved in order to progress with national efforts to meet the 2020 and 2030 targets. Amongst them, the quest for and access to data proved to be a great challenge (e.g. access to the detailed input energy audit data for generating EPCs). To support future work and further analysis, more good quality data would be valuable. On the front end of the EPCs, the growing number of new data could be exploited to periodically refine the corresponding empirical adaptation factors. Analysing the data at different time periods will facilitate the effort to generate more realistic factors that reflect current actual energy use and populate some missing data for certain building typologies.

The model developed in the framework of the Hellenic pilot study requires input data regarding the modernization trend and rates of refurbishment for different envelope components and heating systems at various modernization levels. For the sake of the EPISCOPE pilot project the model was run using hypothetical data for some inputs. The structure of the developed model permits an easy future update of the current input data. It can also be used for sensitivity analysis in order to assess a sufficiently large number of scenarios to derive the optimum combination of modernization rates that must be included in energy efficiency national action plan to meet the national targets related to CO_2 reduction.

Sources / References <GR> Greece

Table 30: Sources / References <GR> Greece

Reference shortcut	Concrete reference (in respective language)	Short description (in English)
[Balaras 2016]	C.A. Balaras, E.G. Dascalaki, P. Droutsa, S. Kontoyiannidis (2016): Bottom-up Assessment of Hellenic Residential Building Stock Energy Performance, ASHRAE 2016 Annual Winter Conference, 8 p., Orlando, FL, 23-27 January, 2016, manuscript submitted for publication	Overview of the efforts and outline of the results from the Hellenic pilot action for identifying the most popular ECMs for residential buildings, the differences of estimated and real energy savings from ECMs and the derived adaptation coefficients to support a bottom-up assessment of Hellenic residential building stock energy performance.
[buildingcert 2014]	Υπουργείο Παραγωγικής Ανασυγκρότησης, Περιβάλλοντος & Ενέργειας, και ΚΑΠΕ (2014): Μητρώο Ενεργειακών Επιθεωρητών & Αρχείο Ενεργειακών Επιθεωρήσεων. Available online (restricted access): www.buildingcert.gr [2015-09-07]	Official national registry of energy performance certificates (EPCs) and energy inspectors.
[CRES 2014]	Κέντρο Ανανεώσιμων Πηγών και Εξοικονόμησης Ενέργειας (ΚΑΠΕ) (2014): ΕΘΝΙΚΟ ΣΧΕΔΙΟ ΔΡΑΣΗΣ ΕΝΕΡΓΕΙΑΚΗΣ ΑΠΟΔΟΣΗΣ ύμφωνα με την παρ.2 του Άρθρου 24 της Οδηγίας 2012/27/ΕΕ, Αθήνα, Δεκέμβριος 2014. Available online: http://ec.europa.eu/energy/en/topics/energy-efficiency/energy-efficiency-directive/national-energy-efficiency-action-plans [2015-09-07]	YPEKA - National Energy Efficiency Action Plan Pursuant to Article 24(2) of Directive 2012/27/EU, Athens: Hellenic Ministry of Environment, Energy and Climatic Change, December 2014.
[Dascalaki 2011]	E.G. Dascalaki, K.G. Droutsa, C.A. Balaras, S. Kontoyiannidis (2011): Building Typologies as a Tool for Assessing the Energy Performance of Residential Buildings – A Case Study for the Hellenic Building Stock, Energy & Buildings 43 (2011) 3400-3409. Available online: http://dx.doi.org/10.1016/j.enbuild.2011.09.002	Overview of the Hellenic TABULA residential typologies along with an assessment of various ECMs that are used for an estimate of the energy performance of building stock in Greece in an effort to meet the 9% indicative national energy savings target by 2016.
[Dascalaki 2012]	E.G. Dascalaki, C.A. Balaras, A.G. Gaglia, K.G. Droutsa, S. Kontoyiannidis (2012): Energy Performance of Buildings - EPBD in Greece, Energy Policy 45 (2012) 469-477. Available online: http://dx.doi.org/10.1016/j.enpol.2012.02.058	Overview of EPBD related work in Greece, including the general process, main characteristics of technical guidelines and tool.
[Dascalaki 2014]	Ε.Γ. Δασκαλάκη, Κ.Α. Μπαλαράς, Κ. Δρούτσα, Σ. Κοντογιαννίδης (2014): Τυπολογία ελληνικών κτιρίων κατοικίας – Δυναμικό εξοικονόμησης ενέργειας. Available on line (in Greek): http://episcope.eu/fileadmin/tabula/public/docs/brochure/GR_TABULA_TypologyBrochure_NOA.pdf [2015-09-11]	Updated Hellenic brochure on the “Typology of Hellenic residential buildings – Energy conservation potential”

Reference shortcut	Concrete reference (in respective language)	Short description (in English)
[Dascalaki 2016]	Ε.Γ. Δασκαλάκη, Κ.Α. Μπαλαράς, Κ. Δρούτσα, Σ. Κοντογιαννίδης (2016): Δυνατότητες και προοπτική για την ενεργειακή αναβάθμιση του ελληνικού κτιριακού αποθέματος, EPISCOPE D3.2b/P07 (NOA) Τελική έκδοση, Αθήνα. Available online http://episcope.eu/fileadmin/episcope/public/docs/pilot_actions/GR_EPISCOPE_NationalCaseStudy_NOA.pdf [2016-03-15]	Overview of the Hellenic pilot action performed within EPISCOPE. Detailed overview of available national data and results of the work, national building stock characteristics, field audit and survey results, empirical adaptation factors, moving towards the national energy saving and CO_2 abatement targets for 2020 and 2030.
[ELSTAT 2013]	Ελληνική Στατιστική Αρχή (2013): Έρευνα Κατανάλωσης Ενέργειας στα Νοικοκυριά 2011-2012, Αθήνα. Available at (summary): http://www.statistics.gr/portal/page/portal/ESYE/BUCKET/A0805/PressReleases/A0805_SFA40_DT_5Y_00_2012_01_F_EN.pdf [2015-07-23]	National survey (2011-12) published by the Hellenic Statistical Authority (ELSTAT) on energy consumption in households, end uses (space heating – cooling, domestic hot water, lighting, etc.), energy carriers, energy consumption habits, type and number of devices and systems used, penetration of energy efficiency technologies, socio-economic characteristics.
[ELSTAT 2015]	Ελληνική Στατιστική Αρχή (2015): Απογραφή κτιρίων και οικοδομών 2001 και 2011, Αθήνα. Available online (summary): http://www.statistics.gr/portal/page/portal/ESYE/PAGE-census2011 [2015-07-23]	National census data (2001 and 2011) published by the Hellenic Statistical Authority (ELSTAT) on the number of buildings of Greece and their characteristics (e.g. number of floors and dwellings, use and period of construction, construction material, type of roof and ownership), as recorded during the 2001 and 2011 Buildings Census.
[EU 2014.v3]	European Commission – DG Energy (2014): Country Factsheets, 2014 version 3.0. Available online: https://ec.europa.eu/energy/sites/ener/files/documents/2014-country-factsheets.pdf [2015-09-07]	Historic energy balance data for all EU countries from Eurostat, DG ECFIN, EEA, IEA.
[KENAK 2010]	Υπουργείο Παραγωγικής Ανασυγκρότησης, Περιβάλλοντος και Ενέργειας (ΥΠΕΚΑ) (2010): Κοινή Υπουργική Απόφαση «Έγκριση Κανονισμού Ενεργειακής Απόδοσης Κτιρίων» Available online: http://www.ypeka.gr/?tabid=525 [2015-09-07]	KENAK - Hellenic Regulation on the Energy Performance in the Building Sector, Hellenic Ministry of Environment, Energy and Climatic Change – YPEKA, Ministerial Decision D6/B/5825 (Official Journal of the Hellenic Republic FEK 407/B/9.4.2010).
[N.3851/2010]	Νόμος 3851, Επιτάχυνση της ανάπτυξης των Ανανεώσιμων Πηγών Ενέργειας για την αντιμετώπιση της κλιματικής αλλαγής και άλλες διατάξεις σε θέματα αρμοδιότητας του Υπουργείου Περιβάλλοντος, Ενέργειας και Κλιματικής Αλλαγής, ΦΕΚ 85/Α/04.06.2010. Available online (in Greek): https://www.buildingcert.gr/nomiko_plaisio/3851_2010.pdf [2015-09-07]	National legislation for accelerating the development of renewable energy sources to deal with climate change, set national targets for renewables until the end of 2020 based on Directive 2009/28/EC
[N.4122/2013]	Νόμος 4122, Ενεργειακή Απόδοση Κτιρίων – Εναρμόνιση με την Οδηγία 2010/31/ΕΕ του Ευρωπαϊκού Κοινοβουλίου και του Συμβουλίου και λοιπές διατάξεις, ΦΕΚ 42 Α/19.02.2013. Available online (in Greek): https://www.buildingcert.gr/N4122_2013.pdf [2015-09-07]	National legislation for the transposition of the EPBD recast (2010/31/EU)
[Stein/Loga/Diefenbach 2014]	EPISCOPE project team (2014): Inclusion of New Buildings in Residential Building Typologies, EPISCOPE project, D2.4, October 2014. Available on line: http://episcope.eu/fileadmin/episcope/public/docs/reports/EPISCOPE_SR1_NewBuildingsInTypologies.pdf [2015-09-11]	EPISCOPE Synthesis Report No1; examples of NZEB definitions in different European countries

3.6 <IT> Italy

Regional Residential Building Stock of Piedmont Region

(by EPISCOPE partner POLITO)

Observed Building Stock and Aims of the Scenario Analysis

The Italian pilot action of EPISCOPE focuses on the Piedmont region, in the Northwest of Italy. The main data of the observed building stock are shown in Table 31. The objective of the pilot action is the contribution to monitoring the current state of the regional residential building stock in terms of energy performance, and the scenario analysis is finalised to the optimization of the energy refurbishment processes and energy savings related to the same stock. The results are addressed to local authorities to help them at setting up corrective actions to foster the most effective and efficient refurbishment measures.

A statistical analysis carried out on the building energy performance certificate (EPC) database of Piedmont region (as the main energy-related data source for *monitoring indicators*) revealed that around 63 % of the floor area of the residential building stock (RBS) has external uninsulated walls and the 42 % of the RBS floor area presents single glazing windows. Globally, the 41 % of the regional housing floor area has centralized heating systems, while the 52 % is provided with individual heating systems. The most widespread heat generators are the standard non-condensing gas boiler (68.5 %) and the condensing gas boiler (18 %), followed by the district heating (7.1 %), while the biomass heat generators and the heat pumps cover less than 3 %. The average annual rate of the retrofitted dwellings in Piedmont is around 2 %, considering partial refurbishment actions. The most commonly applied measures are windows and heat generator replacements, while the least applied measures are the insulation of vertical and horizontal building components [Nocera 2011-14].

The scenario calculations were performed considering some reference benchmarks as the climate protection targets. The Italian targets on CO_2 emissions for some reference years are provided by a report from the national energy agency which presents scenarios and strategies towards a *low carbon* country [ENEA 2013]. The targets are based both on the “Decision 406/2009/EC” and on the “Roadmap 2050” (2011). The national targets, which are expressed as a percentage reduction of CO_2 emissions compared to the values in 1990, are assumed to be applied to Piedmont region likewise, as no information is available at a regional level.

Table 31: Scope of the observed building stock in <IT> Italy [ISTAT 2011]

Scale	**No. of dwellings**	**No. of buildings**	**No. of inhabitants**	**m² national reference area** (conditioned floor area)	**m² EPISCOPE reference area**
Regional	~ $2.44 \cdot 10^6$	~ $0.945 \cdot 10^6$	~ $4.36 \cdot 10^6$	~ $214 \cdot 10^6$ m^2	~ $214 \cdot 10^6$ m^2

Scenario Approach

Monitoring indicators and model assumptions concerning data on the building envelope and thermal system characteristics were identified for the definition of both the Basic Case, which represents the current situation of the residential building stock of Piedmont region, and the scenario analyses. As regards the model assumptions, they were chosen as to represent the most probable conditions and by adopting a reasonable compromise between the advantages and disadvantages of their application within the Basic Case and the scenarios.

The calculations of the energy performance of the Basic Case and the scenarios were performed by using some representative buildings of the regional residential building stock derived from the “Building Type Matrix” of the TABULA project [Corrado et al. 2014]. The frequency of each building-type within the stock allowed to quantify the energy performance of the entire regional housing stock.

The scenarios concerning the energy refurbishment of the housing stock differ from each other for the following properties:

- types of retrofit actions and requirements of the energy efficiency measures,
- amount of refurbishment actions in the building stock,
- energy and environmental performance resulting from the application of the actions.

Depending on the scenario, the second and the third listed properties represent alternatively the input and the output data (i.e. the result) of the analysis.

The calculation of the Basic Case and the scenarios energy performance was carried out according to the procedure of the technical specification UNI/TS 11300 [UNI 2014], which is the Italian calculation method for the building energy certification and the compliance verification of minimum energy performance requirements for new and existing buildings.

Data Sources

The current state of the housing stock in Piedmont region and the trend of building energy refurbishments were determined by means of statistical data. These data were derived either directly or by processing from the following data sources:

- census of population and dwellings by the National Institute of Statistics [ISTAT 2011],
- reports from the observatory of the real estate market [OMI 2013],
- database of the building energy performance certificates of Piedmont Region,
- reports of the National Agency for New Technologies, Energy and Sustainable Economic Development (ENEA) [Nocera 2011-14].

Among the above references, the main energy-related data source of monitoring indicators for the Piedmont regional pilot action is the database of the building EP certificates (EPCs). In 2009, the Piedmont Region issued an information system for the energy performance certification of buildings (SICEE). The system allows the qualified professionals to compile the certificates and to transmit them to the regional authorities, which in turn analyze and collect the certificates in a database. This database has a limited access and its use is restricted at statistical purposes and research activity.

A statistical analysis was carried out on the EPC database, which includes all the EP certificates delivered from 2010 to 2013. The objective of the analysis has been the identification of the thermal insulation state of the building envelope and the thermal system features of the existing housing stock. A preliminary activity consisted in removing inconsistencies from the database. These may occur both in the main parameters object of analysis (e.g. the wall U-value) and in the normalizing parameters (e.g. the conditioned net floor area). Due to the heterogeneous origin of the data, errors may occur in measurements and evaluations generated by differences in the professionals skills.

A statistical analysis also focused on the identification of the monitoring indicators concerning the recent energy refurbishment rates of the regional housing stock. The main information was derived from ENEA reports on the “demands of tax deduction for the energy refurbishment of existing buildings” [Nocera 2011-14]. The average building stock floor area annually refurbished was got from the number of dwellings refurbished in the period ranging from 2008 to 2012 by type of energy efficiency measure.

Description of the Basic Case and the Most Relevant Scenarios

The monitoring indicators referring to the current state of the housing stock were grouped to constitute the Basic Case properties. The Basic Case, which is shown in Figure 16, is characterised by indicators of the building envelope and indicators of the thermal system. The former are separately related to the vertical opaque enclosures and to the windows, of which eight and four U-value ranges have been defined respectively. The latter are represented by nine different heat generators, each of which is characterised by a specific energy carrier. The current state of the regional housing stock is defined by means of combinations of walls and windows U-value ranges and heating system types for each construction period. Each combination represents a percentage of the total residential building stock (RBS) floor area.

The RBS floor area was clustered in such a way as to assume that increasing heating system efficiency corresponds to decreasing U-values of walls and windows. The black segments in Figure 16 identify, for each construction period, from 1 up to 6 different efficiency levels (numbers in the circles), for a total of 28 combinations which represent the 94 % of the total RBS floor area of Piedmont region. The remaining 6 % is discarded as it consists of not representative conditions, like high energy efficiency levels in the oldest construction periods and low energy efficiency solutions in the latest age classes.

The Basic Case, which consists in the starting point of trend and scenario calculation of the regional pilot action, was modelled using the geometry of some representative residential buildings from the TABULA project [Corrado et al. 2014].

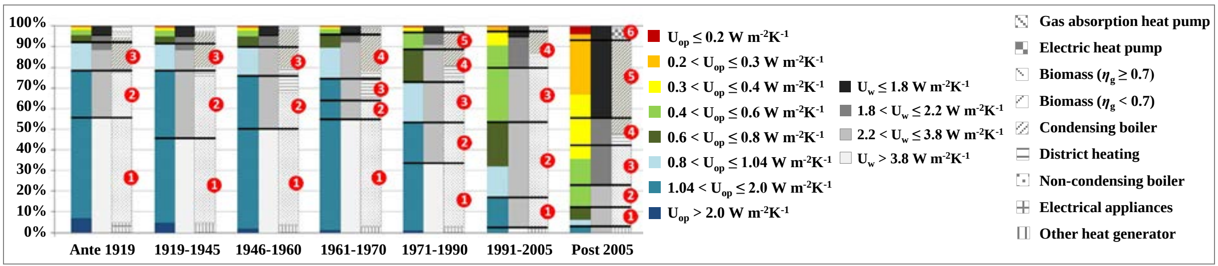


Figure 16: Basic Case of the Piedmont residential building stock (the percentages are referred to the RBS floor area)

The properties of the three most relevant scenarios developed in the analysis are listed in Table 32, in terms of types of retrofit actions (partial and/or global) and requirements of the related energy efficiency measures. In addition for each scenario, the *input* and *output* data concerning alternatively the amount of refurbishment actions in the building stock and the energy and environmental performance resulting from the application of the actions are pointed out.

Table 32: Properties of the developed scenarios

Scenario properties	Scenario name		
	TREND SCENARIO	***COST-OPTIMAL SCENARIO***	***TARGET SCENARIO***
Types of retrofit actions	Both partial and global building refurbishment	Both partial and global building refurbishment	Global building refurbishment
Requirements of the energy efficiency measures	From a regional decree [Regione Piemonte 2009]	From the national cost-optimal comparative methodology [Corrado et al. 2013; MiSE 2013]	From a regional decree [Regione Piemonte 2009]
Input / output data			
Amount of refurbishment actions in the RBS	*INPUT:* Current annual trend of improvements		*OUTPUT:* Percentage of RBS floor area to be annually refurbished
Performance resulting from the application of the actions	*OUTPUT*: Comparison with the climate protection targets		*INPUT:* Keeping the climate protection targets at 2020, 2030 and 2050

Results

The comparison between the results of the most relevant scenarios developed is presented in Table 33. The results are shown in terms of *Summary Indicators*, which consist in the following annual quantities:

- CO_2 emissions ($m_{CO2,heat\ supply}$);
- total heat demand (q_{total});
- CO_2 emission factor heat supply ($f_{CO2,heat\ supply}$).

The EPISCOPE and individual (national) climate protection targets, in terms of CO_2 emission benchmarks at 2020, 2030 and 2050, are shown in Table 33 by means of a dashed and continuous red line respectively. As it can be noted, the *Trend Scenario* and the *Cost-optimal Scenario* do not reach the 2030 and 2050 targets far and they do not achieve the 2020 benchmark for a little amount.

Both the *Trend Scenario* and the *Cost-optimal Scenario* follow the actual trend of energy refurbishment in Piedmont region and present similar results, even if different energy efficiency measures and requirements are applied. In fact, the *Trend Scenario* applies the most common measures whose requirements (e. g. U-values of the building envelope components) are fixed by a regional decree [Regione Piemonte 2009]; while, the *Cost-optimal Scenario* considers the cost-optimal requirements for the energy efficiency measures got from the national application of the comparative methodology complying with Article 5 of Directive 2010/31/EU (*EPBD recast*) [Corrado et al. 2013], [MiSE 2013].

Although the *Cost-optimal Scenario* determines results similar to the *Trend scenario*, the retrofit actions of the *Cost-optimal Scenario* should be preferable because even the economic implications are taken into account.

The sole scenario that attains the national climate protection targets in the reference years is the *Target scenario*, as it has been really created at this scope in order to discover the annual trend of energy refurbishment that should be followed to reach the targets. The effective trend would consist in a global energy refurbishment of 2 % of the regional residential building stock floor area every year, although considering the same technologies and the energy efficiency requirements of the *Trend Scenario*. The current trend of improvements is therefore inadequate, as it is based above all on partial building renovations, and the annual global actions involving both the building envelope and the thermal systems are just 0.1 % of the housing stock floor area.

The effectiveness of the *Target scenario* is also displayed in the total heat demand of the residential building stock in 2050 which is reduced of about 72 % with respect to the Basic Case. On the contrary, the less effective scenarios present a reduction of 17 % with respect to the starting point.

The CO_2 emission factor heat supply presents a very low variability in every scenario, because it has been assumed, as a precaution, that substantial changes do not occur to the types of energy carriers supplied in the analysed period (see also Table 34).

The same trend of new residential buildings was applied in all scenarios. It follows the current annual trend of 0.44 %, according to [ISTAT 2011] and [OMI 2013]. The characteristics of the new buildings correspond to the highest efficiency level of the Basic Case for the construction period after 2005 (see Figure 16). No demolitions were considered in the analysis as they do not still represent a common practice in Italy.

Table 33: Summary Indicators <IT> Italy

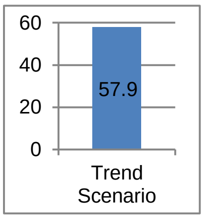
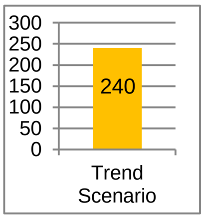
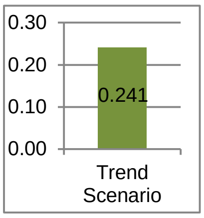
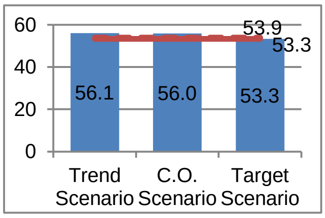
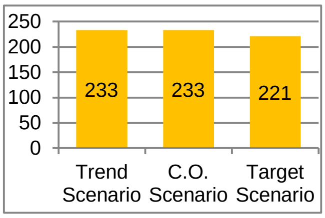
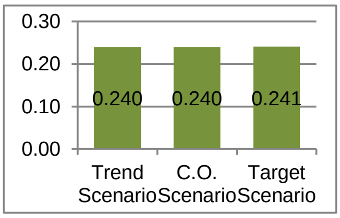
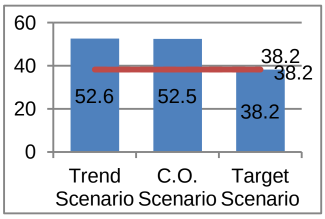
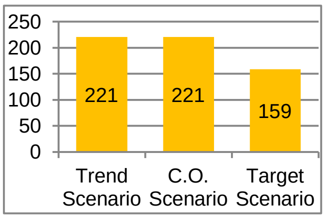
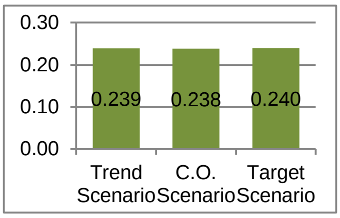
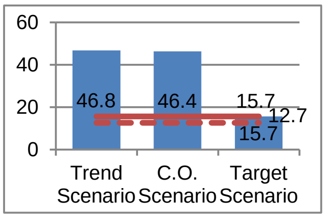
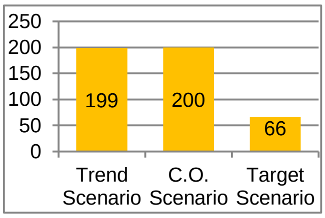
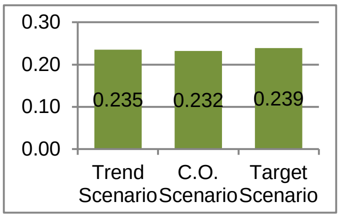
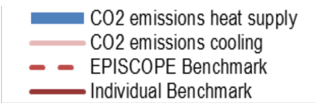
	EPISCOPE Ref. Area	CO_2 emissions	Total heat demand	CO_2 emission factor heat supply
	10^9 m²	kg/(m²yr)	kWh/(m²yr)	kg/kWh
2015	0.214			
2020	0.219			
2030	0.227			
2050	0.245			
Explanation				
		$m_{CO2,heat\ supply}$: annual carbon dioxide emissions (related to EPISCOPE reference area) $m_{CO2,heat\ supply} = q_{total} \times f_{CO2,heat\ supply}$ 	q_{total}: total heat demand (heat generation for space heating and DHW, related to EPISCOPE reference area)	$f_{CO2,heat\ supply}$: total CO_2 emission factor of heat supply
Comments				
Trend Scenario: observed state and trends in the regional building stock in 2015 Cost-optimal (C.O.) Scenario: actual trends and cost-optimal energy performance requirements Target Scenario: keeping the national targets at years 2020, 2030, 2050				

Table 34: Final energy by fuel <IT> Italy, gross calorific value [GWh/yr]

	2015	2020			2030			2050		
Absolute figures	Trend Scenario	Trend Scenario	C.O. Scenario	Target Scenario	Trend Scenario	C.O. Scenario	Target Scenario	Trend Scenario	C.O. Scenario	Target Scenario
natural gas	63990	62989	62809	59728	61003	60464	43058	57464	56502	16983
liquid gas	0	0	0	0	0	0	0	0	0	0
oil	0	0	0	0	0	0	0	0	0	0
coal	0	0	0	0	0	0	0	0	0	0
wood / biomass	0	0	0	0	0	0	0	0	0	0
district heating	1125	1123	1123	1123	1121	1121	1121	1078	810	234
electric energy (used for heat supply)	915	992	1037	992	1146	1281	1146	1453	1766	1453

Conclusions

The scenario analyses on the energy refurbishment of the residential building stock of Piedmont region highlighted that if the current trend of improvements is followed, the reductions of the energy demand and the CO_2 emissions are very poor. These results do not allow the climate protection targets to be reached in the reference years, although different energy efficiency measures and requirements are set for the building envelope components and the thermal systems. In order to attain more satisfying results, the retrofit actions should be rather addressed to the type of refurbishment (global and not partial renovations) and to the amount of residential floor area to be annually retrofitted, as occurs in the *Target Scenario*.

This conclusion is quite in line with the objectives of the Italian law no. 90 (August 2013) which adopts the Directive 2010/31/EU at national level. With reference to the promotion of financial instruments, the national law requires that the incentives adopted by the State, the regions and the local authorities to promote the energy efficiency in buildings will be granted not only in respect of energy efficiency requirements related to the building type, the building use and the context in which the building is located, but also in respect of the extent of the retrofit action.

In a precautionary way, the *Trend Scenario* and the *Cost-optimal Scenario* consider construction and system technologies commonly applied in the national and regional territory, even if the increase in the use of renewable energy sources has been reasonably supposed.

Among the renewable energy sources, the thermal solar system for the domestic hot water (DHW) production was applied in every scenario, while the photovoltaic system was foreseen in the *Cost-optimal Scenario.* The former technology is the most applied in Piedmont, while the latter is spreading. The biomass was not considered in the analysis because it has a limited application in the regional territory (less than 2.5 %). Anyway, the *Target Scenario* already allows to attain the targets without applying highly innovative technologies. In fact the targets can be easily reached if just 2 % of the residential building stock floor area is annually renovated, by considering thermal insulation measures characterised by U-values of 0.33 $W{\cdot}m^{-2}K^{-1}$ for external walls, 0.3 $W{\cdot}m^{-2}K^{-1}$ for ceilings and floors, 2 $W{\cdot}m^{-2}K^{-1}$ for windows, and installing a condensing boiler for space heating and DHW, a thermal solar system covering 50 % of the energy need for DHW and an efficient heating control system. Of course, if more innovative technologies are applied, the annual 2 % of floor area to be globally refurbished could be reduced.

In the choice of the energy efficiency measures and the related minimum energy performance requirements, those of the *Cost-optimal Scenario* are preferable, because they lead to the lowest global cost in the building life cycle. However, only global renovations should be applied in order to guarantee the effectiveness of the *Cost-optimal scenario*.

The scenario analyses are mainly addressed to the local administrations. In order to reach the climate protection targets at short, medium and long term, the key actors should be boosted at:

– promoting large-scale interventions by means of incentives that encourage a global building refurbishment and identifying guidelines for technical and economic feasibility;
– improving the monitoring of the housing stock, by increasing the availability and the quality of data, in order to develop and update the scenario analyses and obtain more reliable results on the energy saving and CO_2 reduction potentials.

As concerns the scenario analyses, a future research activity will investigate the effect of the application of updated energy performance requirements in the refurbishment actions, according to new energy efficiency levels set by the forthcoming decree that implements the Italian law no. 90/2013.

Sources / References <IT> Italy

Table 35: Sources / References <IT> Italy

Reference shortcut	Concrete reference (in respective language)	Short description (in English)
[Corrado et al. 2013]	Corrado, V./Ballarini, I./Paduos, S. (2013): Sviluppo della metodologia comparativa cost-optimal secondo Direttiva 2010/31/UE, ENEA RdS/2013/144.	The report is an upgrading of [MiSE 2013]. Besides analysing global building renovations, it includes the identification of cost-optimal energy requirements for partial building refurbishments.
[Corrado et al. 2014]	Corrado, V./Ballarini, I./Corgnati, S. P. (2014): Building Typology Brochure – Italy. Fascicolo sulla Tipologia Edilizia Italiana. EPISCOPE - D2.3.	EPISCOPE – Deliverable 2.3, corcerning an updated version of the Building Typology Brochure of the TABULA project.
[ENEA 2013]	ENEA (2013): Rapporto Energia e Ambiente, Scenari e strategie. Verso un'Italia low carbon: sistema energetico, occupazione e investimenti. Agenzia nazionale per le nuove tecnologie, l'energia e lo sviluppo economico sostenibile (ENEA), Roma.	The report from the Italian national energy agency presents scenarios and strategies towards a *low carbon* country and provides the climate protection targets up to 2050.
[ISTAT 2011]	ISTAT (2011): Censimento della popolazione. Elaborazioni dell'Istituto Nazionale di Statistica (http://www.istat.it/it/).	Statistical data of the census carried out in 2011 by the National Institute of Statistics.
[MiSE 2013]	Ministero dello Sviluppo Economico (MiSE) (2013): Applicazione della metodologia di calcolo dei livelli ottimali in funzione dei costi per i requisiti minimi di prestazione energetica (Direttiva 2010/31/UE Art. 5), Available at: http://ec.europa.eu/energy/efficiency/buildings/doc/2013_it_cost-optimal_en.zip [2015-07-22]	The report provides the results of the national application of the comparative methodology for the calculation of the cost-optimal levels for minimum energy performance requirements, complying with article no. 5 and annex III of Directive EPBD recast (2010/31/EU) on the energy efficiency of buildings.
[Nocera 2011-14]	Nocera, M. (2011-2014): Le detrazioni fiscali del 55% per la riqualificazione energetica del patrimonio edilizio esistente – Anni 2008-2012. Agenzia nazionale per le nuove tecnologie, l'energia e lo sviluppo economico sostenibile (ENEA), Roma.	The reports, yearly delivered from 2011 to 2014 by the Italian national energy agency, provide data concerning the demands of tax deduction for the energy refurbishment of the existing buildings at regional level from 2008 to 2012.
[OMI 2013]	OMI (2013): Rapporto immobiliare 2013. Osservatorio del Mercato Immobiliare.	The report provides data on the new residential buildings in Piedmont region from 2000 to 2012.
[Regione Piemonte 2009]	Deliberazione della Giunta Regionale 4 agosto 2009, n. 46-11968 "Aggiornamento del Piano regionale per il risanamento e la tutela della qualità dell'aria – Stralcio di piano per il riscaldamento ambientale e il condizionamento e disposizioni attuative in materia di rendimento energetico nell'edilizia ai sensi dell'articolo 21, comma 1, lettere a) b) e q) della legge regionale 28 maggio 2007, n. 13 Disposizioni in materia di rendimento energetico nell'edilizia", pubblicata sul Bollettino Ufficiale della Regione Piemonte n. 31, supplemento n. 4 del 7 agosto 2009.	The regional decree, which is still in force in Piedmont, provides minimum energy performance requirements of building envelope components and thermal systems which have to be applied in the energy refurbishment of existing buildings.
[UNI 2014]	UNI/TS 11300, Prestazioni energetiche degli edifici – Parti 1 e 2 (ottobre 2014) e parte 4 (maggio 2012), Ente Nazionale Italiano di Unificazione.	Technical specification providing the Italian calculation method for the building energy certification and the compliance verification of minimum energy performance requirements for new and existing buildings.

3.7 <NL> The Netherlands

National Non-Profit Housing Stock

(by EPISCOPE partner DUT)

Observed Building Stock and Aims of the Scenario Analysis

Nearly all homes in the Dutch non-profit (or social) housing sector are owned and managed by housing associations, which are private organisations that have a legal obligation to provide sufficient affordable housing for low-income households. The sector counts 2.3 million homes, which is 31 % of the total housing stock [BZK 2013]. This is a unique situation as the Netherlands have the highest percentage of non-profit housing in the European Union. The size of the sector is further illustrated in Table 36.

Table 36: Scope of the observed building stock in <NL> The Netherlands
[CFV 2014], [Statistics Netherlands 2012], [BZK 2013], [SHAERE 2013]

Scale	No. of dwellings	No. of buildings	No. of inhabitants	m² national reference area	m² EPISCOPE reference area*
national non-profit rental housing	2,267,199	Not available	~ 4,990,000	191.413×10^6 total net floor area	210.555×10^6

* This figure, referring to the area within the building envelope, is calculated by adding 10 % to the national reference area, which refers to the living area within the homes only. This 10 % has been found in [Loga & Diefenbach 2013].

At the end of 2013, 63 % of the Dutch non-profit dwellings had a high-efficiency gas boiler ($\eta \geq 95$ %). Heat pumps, PV panels and solar boilers are not very common, but their number is increasing rapidly. Whereas the vast majority of dwellings is in some way insulated (for example, 96 % have double glazing or better insulating glazing [Aedes 2015]), still 52 % of the dwellings have none or very poor wall insulation [SHAERE 2013].

In the years 2011-2013, 35.5% of the dwellings had a change in installations/systems and/or a change in insulation category. However, in nearly 2/3 of these cases only one measure was taken. In only 3 % of the improved dwellings more than three measures were implemented [Aedes 2015].

In 2012 the national umbrella organisation for housing associations agreed in a covenant with some other parties that in 2020 the average Energy Index of all homes of the Dutch housing associations must be 1.25 [BZK et al. 2012], which is within the bands of energy performance rate B (in the Netherlands categories ranging from A++ (very high energy efficiency) to G (very low energy efficiency) are used). This means a reduction of energy consumption of around 30 % compared with the current situation.

Scenario Approach

The scenarios in this chapter are constructed on the basis of the mix of homes in the Dutch non-profit housing stock. In the scenarios this mix is constructed on the basis of a classification of housing types and, for each of the classes in this typology, the extent of renovation.

- For the classification of housing types, the Dutch housing typology, as described in [AgentschapNL 2011] and [AgentschapNL 2013], is followed, including the average buildings per class given in these publications. This information is also available in the TABULA data base and WebTool [EPISCOPE 2015]. The ‘average buildings’ are buildings of which the size of each of the elements is the average of all buildings in the building class and which contain the most frequent systems/installations in that class. As such, average buildings can be regarded as representative for the building class to which they belong.
- For the extent of renovation the three classes in the TABULA concept are used, namely unrenovated, usual refurbishment (renovated according to currently usual energy stand-

ards) and advanced refurbishment (renovated according to advanced energy standards). For unrenovated homes, the data about the present state are used; the description of usual refurbishment is based on current legal standards and frequently applied changes of glass and installations; for advanced refurbishment, measures in [AgentschapNL 2013] to attain an nZEB level are taken. This includes the introduction of on-site renewable energy generation (solar panels, heat pumps).

- In the information from [AgentschapNL 2011] possible energy renovations and other improvements carried out in the past are already included in the data regarding the average buildings. This information thus represents the present state, not the original state.

Data Sources

As mentioned above, the SHAERE monitor and building characteristics from AgentschapNL are the most important information sources. For the calculations per class in the building typology, existing data in the TABULA data base are used. These data were once inserted in the data base on the basis of information from AgentschapNL about reference homes per class in the Dutch building typology. From SHAERE the actual number of homes per class has been derived.

Description of the Basic Case and the Most Relevant Scenarios

The composition of the non-profit housing stock is calculated on the basis of the number of homes in each of the classes of the housing typology. For the end of 2014 or the beginning of 2015 (the reference date for the basic case), these numbers have been found in SHAERE. With these numbers, a weighted average is calculated for the years under consideration, namely 2015, 2020, 2030 and 2050.

Three scenarios are formulated, a trend scenario and scenarios B and C. As the name indicates, the trend scenario follows the average energy improvement rate of the Dutch non-profit housing stock in the past, namely over the years 2010-2014. In this period, the Energy Index (the official Dutch measure for the energy performance of buildings) dropped from 1.81 to 1.65, which is a decrease by 2.3 % per year. This percentage has been applied in the trend scenario for extrapolations.

Scenarios B and C are based on the development of the size of the sector and by the numbers of homes undergoing either a usual refurbishment or an advanced refurbishment, as defined in the TABULA data base. In both scenarios the following assumptions are made.

- The amount of new building will be 1 % of the number of dwellings in 2015 (demographic developments do not justify an annually increasing rate) and it will not affect the housing mix according to type.
- Until and including 2019, the energy performance characteristics of the new homes are the same as those for the newest building year class. As from 2020, when it is assumed that nZEB standards are in force, the level for advanced refurbishment is applied.
- The amount of removals per building year class will be 1 % of the stock at the end of the previous year, except for the newest class (homes built after 2014), in which no homes will be removed.
- Annually 1 % of the number of dwellings older than 25 years will be refurbished.

Scenario B and C differ in the type of refurbishment. In scenario B, all refurbishments are carried out following the *currently usual* standard as described above. In scenario C, refurbishments are carried out following the *advanced* standard. The use of renewable energy is included in this scenario.

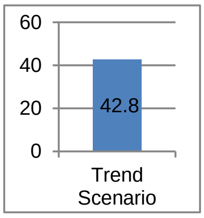
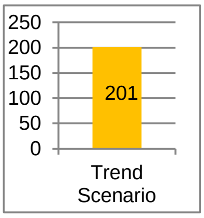
An exception in scenario B is that for dwellings built after 2005 (the two newest building year classes) no usual refurbishment level is defined, because the difference between the present level and the advanced level is too small to also formulate an intermediate level. For these dwellings, the actual energy performance level is taken as the usual refurbishment level.

Results

Table 37 shows the average energy consumption (for heating and warm water) of the dwellings in the Dutch non-profit housing sector, plus the related CO_2 emission level.

The individual benchmark in Table 37 shows the energy consumption level which should be attained if the rate of energy improvement in the housing stock would be just enough to meet the national 2020 target for the non-profit housing stock and if the same rate would continue after that year.

Table 37: Summary Indicators <NL> The Netherlands

<table>
<tr><th></th><th>EPISCOPE Ref. Area</th><th>CO₂ emissions</th><th>Total heat demand</th><th>CO₂ emission factor heat supply</th></tr>
<tr><td></td><td>10^6 m²</td><td>kg/(m²yr)</td><td>kWh/(m²yr)</td><td>kg/kWh</td></tr>
<tr><td>2015</td><td>210.6</td>
<td>
</td>
<td>
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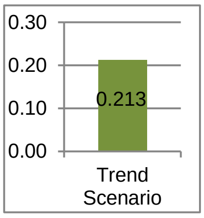
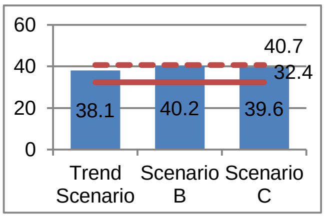
<td>
</td></tr>
<tr><td>2020</td><td>210.7</td>
<td>
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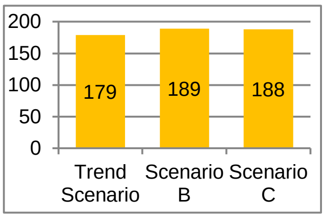
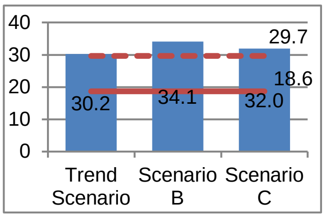
<td>
</td>
<td>
</td></tr>
<tr><td>2030</td><td>212.7</td>
<td>
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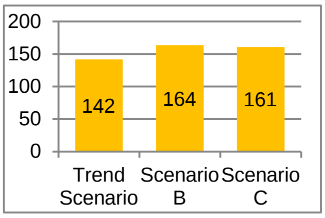
<td>
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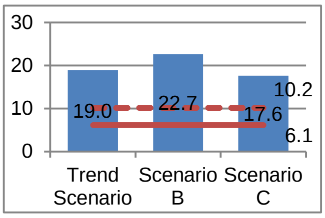
<td>
</td></tr>
<tr><td>2050</td><td>221.8</td>
<td>
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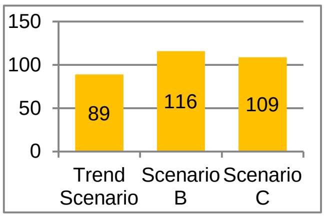
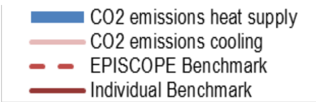
<td>
</td>
<td>
</td></tr>
<tr><td colspan="5">Explanation</td></tr>
<tr><td></td><td></td>
<td>$m_{CO2,heat\ supply}$:
annual carbon dioxide emissions (related to EPISCOPE reference area)
$m_{CO2,heat\ supply} = q_{total} \times f_{CO2,heat\ supply}$

</td>
<td>q_{total}:
total heat demand
(heat generation for space heating and DHW, related to EPISCOPE reference area)</td>
<td>$f_{CO2,heat\ supply}$:
total CO_2 emission factor of heat supply</td></tr>
<tr><td colspan="5">Comments</td></tr>
<tr><td colspan="5">Trend scenario: observed trend in the non-profit housing stock over 2010-2014
Scenario B: annually 1 % of the stock undergoes usual refurbishment
Scenario C: annually 1 % of the stock undergoes advanced refurbishment</td></tr>
</table>

From [Aedes 2015] it is known that the energy improvement rate in the non-profit housing sector in the recent past was insufficient to meet the national target for this sector for 2020. In both scenarios B and C, however, the outcome would be even worse, and this is also true for 2030 and 2050 as far as the total heat demand is concerned. However, in scenario C, the CO_2 emission is estimated to be lower, because a bigger share of the energy need comes from renewable energy sources – a development that is not included in the trend scenario.

It could be concluded that the housing associations, although they are not expected to attain the national target, make good progress compared to the other scenarios. It must be stated, however, that it the current trend is likely to include the so-called low-hanging fruit, so that this trend is unlikely to continue in the long term, meaning that the trend scenario is probably too optimistic. Nevertheless, even in this scenario the calculated average energy use (89 kWh/m^2/year) in 2050 is too high if compared with the commonly used policy target of an 80 % reduction in energy consumption. What the result of scenario C makes clear is that a refurbishment rate of 1 % is too low to reach energy neutrality in the housing stock, unless a massive transition from fossil to renewable energy use will take place.

Because the CO_2 emission is related to the energy consumption, the picture for this emission levels is similar: for 2020 and 2030 the trend scenario gives the highest reduction, while for 2050 scenario C leads to the lowest emission level. For 2020 and 2030 the emission levels in all three scenarios are lower than the EPISCOPE benchmark, but for 2050 they are considerably higher.

As for the energy carriers, there is no reliable information about the energy mix per class in the Dutch building typology, but because energy for heating and warm water is almost exclusively delivered by natural gas, we use the assumption that natural gas is the only energy carrier, with the exception for auxiliary energy, which is delivered by electricity. As a consequence Table 38 presents a slightly simplified overview of energy carriers.

Table 38: Final energy by fuel in the non-profit housing stock in <NL> The Netherlands, gross calorific value [GWh/yr]*

	2015	2020			2030			2050		
Absolute figures	Trend Scenario	Trend Scenario	Scenario B	Scenario C	Trend Scenario	Scenario B	Scenario C	Trend Scenario	Scenario B	Scenario C
natural gas	47,095	41,964	44,304	43,496	33,553	37,211	34,563	21,973	24,236	17,453
electric energy (used for heat supply)	843	n.a.	870	961	n.a.	1,089	1,384	n.a.	1,549	2,292

* For the trend scenario, insufficient data were available to specify the energy consumption according to energy carrier. For gas, the reduction pace for the total energy use has been taken, but this is not realistic for electricity.

The table shows a considerable reduction of gas use in the non-profit sector. Scenario C shows the biggest reduction in the long term. The use of electricity almost doubles in the next 35 years in scenario B and is expected to be almost three times higher in scenario C. This is due to the growth of the number of energy-consuming installations, notably heat pumps. Expressed in GWh, however, the rise in electricity use is almost negligible in comparison with the reduction of gas use.

Conclusions

The results of the scenario calculations do not give reason to be optimistic about the attainability of targets such as an average energy performance level in 2020 in the non-profit housing sector or an 80 % reduction of energy use in 2050. Scenario B clearly shows that continuation of the usual way of refurbishment results in too little progress, at least with a renovation pace of 1 %. But even in scenario C, in which all refurbishments from 2015 and all new building from 2020 meet the nZEB norms, the goals will not be attained. In this scenario a further quality improvement of the respective dwellings does not seem the most appropriate way to proceed: the refurbished and newly built dwellings are already on nZEB level and thus very energy-efficient. Much more can be expected from a higher improvement rate: the 1 %

refurbishment rate included in the scenarios discussed here is too low. This means that incentives for energy improvements must be strengthened and must probably be made more compulsory for housing providers and homeowners than they are now. Further improvements can be found in a modified energy supply structure (e.g. district heating, use of wind energy and geothermal energy) and improved storage facilities for solar energy.

Sources / References <NL> The Netherlands

Table 39: Sources / References <NL> The Netherlands

Reference shortcut	Concrete reference (in respective language)	Short description (in English)
[Aedes 2015]	Aedes (2015): Energetische verbeteringsmaatregelen in de sociale huursector; enkele uitkomsten van de SHAERE-monitor 2010-2013. Online available: http://www.aedes.nl/binaries/downloads/energie-en-duurzaamheid/energetische-verbeteringsmaatregelen-in-de-sociale.pdf [2015-09-01]	Publication of Aedes, the Dutch umbrella organisation for housing associations, and TU Delft containing some results from the SHAERE monitor over the years 2010-2013
[AgentschapNL 2011]	AgentschapNL (2011): Voorbeeldwoningen 2011; Onderzoeksverantwoording. Online available: http://www.rvo.nl/sites/default/files/bijlagen/5.%20Voorbeeldwoning-en%202011%20Onderzoeksverantwoording.pdf [2015-09-01]	Publication containing the Dutch housing typology including data on average insulation and most frequent systems/installations per class for homes built before 2006
[AgentschapNL 2013]	AgentschapNL (2013): Referentiewoningen nieuwbouw 2013. Online available: http://www.rvo.nl/sites/default/files/2013/09/Referentiewoningen.pdf [2015-09-01]	Publication containing six additional classes to the Dutch housing typology, including data on average insulation and most frequent systems/installations, for homes meeting the energy standards of that time
[BZK et al. 2012]	Ministerie van Binnenlandse Zaken en Koninkrijksrelaties, Aedes, Woonbond & Vastgoed Belang (2012): Convenant energiebesparing huursector, Den Haag. Online available: http://www.aedes.nl/binaries/downloads/energie-en-duurzaamheid/20120628-convenant-energiebesparing-huursector-28-.pdf [2015-09-07]	Covenant between the national government, the national body for housing associations, the national body for private landlords and the national tenants' union about reduction of energy consumption in the housing sector
[BZK 2013]	Ministerie van Binnenlandse Zaken en Koninkrijksrelaties (2013): Cijfers over Wonen en Bouwen 2013. Online available: https://www.rijksoverheid.nl/documenten/rapporten/2013/04/11/cijfers-over-wonen-en-bouwen-2013-klikbare-pdf [2015-09-01]	Statistical publication on housing in the Netherlands
[CFV 2014]	Centraal Fonds Volkshuisvesting (2014): Sectorbeeld 2014. Online available: http://www.cfvpublicaties.nl/FbContent.ashx/pub_1001/Downloads/Sectorbeeld_2014.pdf [2015-09-01]	This report goes into the financial situation of the Dutch housing associations.
[EPISCOPE 2015]	EPISCOPE project team (2015): TABULA WebTool. Online available: http://episcope.eu/building-typology/webtool/ [2015-09-04]	TABULA WebTool including national building typologies from various European countries
[Loga & Diefenbach 2013]	Loga, T. & Diefenbach, N. (2013): TABULA Calculation Method – Energy Use for Heating and Domestic Hot Water – Reference Calculation and Adaptation to the Typical Level of Measured Consumption, Darmstadt: Institut Wohnen und Umwelt. Online available: http://episcope.eu/fileadmin/tabula/public/docs/report/TABULA_CommonCalculationMethod.pdf [2015-09-01]	This report deals with several calculation methods in the TABULA software.
[SHAERE 2013]		Own calculations based on the monitor SHAERE, figures for December 31st, 2013
[Statistics Netherlands 2012]	Centraal Bureau voor de Statistiek (2012): Woononderzoek Nederland, Energiemodule	Survey among Dutch households about their energy behaviour and the energy performance of their homes

3.8 <NO> Norway

National Residential Building Stock

(by EPISCOPE partner NTNU)

Observed Building Stock and Aims of the Scenario Analysis

According to the most recent statistics published 22 April 2015 [SSB 2015] the national Norwegian residential building stock per 31 December 2013 has in total 2,466,363 dwellings (occupied and vacant). Of these dwellings 52.0 % are detached houses, 22.7 % are flats in multi-dwelling buildings, 11.5 % are dwellings in row houses, linked houses and houses with three or four dwellings, 9.1 % are houses with two dwellings and 1.9 % dwellings in residences for communities. The remaining 2.7 % are dwellings registered in buildings where the main part of the floor space is used for purposes other than dwellings; mainly industrial buildings. From 2012 to 2014, there was a net growth in the number of dwellings of 44,000, of which almost half were apartment blocks. This corresponds to some 1.8 % increase during two years; which shows that the Norwegian national dwelling stock is growing as a result of population growth and welfare. This growth is mainly in urban areas.

A summary of building stock data for occupied dwellings in the Norwegian residential building stock is shown in Table 40. The EPISCOPE reference area value, equivalent to the heated floor area of occupied dwellings, is assumed to be on average 85 % of the national utility reference area (in Norwegian called 'bruksareal', BRA, of occupied dwellings).

Table 40: Scope of the observed building stock in Norway per 2013-12-31 [SSB 2014a]

Scale	No. of dwellings	No. of buildings	No. of inhabitants	m² national reference area	m² EPISCOPE reference area
National	~ 2.45 million	~ 1.51 million	~ 5.11 million	~ 0.287×10^9 m² (BRA: Bruksareal)	~ 0.244×10^9 m²

The sources of heat supply are very different in Norway compared to most other countries, as heat is provided mainly by electricity. The most recent data, from 2012, show that 94 % of dwellings have electric space heaters or electric floor heating, 66 % have wood stove or open fireplace (with 60 % closed stove for fuel wood), 4 % district heating and 27 % heat pump (ambient-air, geothermal or ground-source) [SSB 2014b]. The shares of energy carriers delivered to the residential building stock in 2012 are electricity (79.3 %), oil and kerosene (3.5 %) and biofuel (15.8 %), the latter dominated by wood.

The state of thermal building insulation is examined on the background of a representative sample of the national dwelling stock [Enova 2012]. This study concludes that a large share of the standing residential building stock in 2010 is still in its original state, e.g. about 22-25 % of all buildings constructed between 1956 and 1970, and 61 % (SFH), 39 % (TH) and 29 % (AB) of buildings constructed from 1971 to 1980. However, there is high uncertainty in the aggregated energy-saving effects of historical renovation measures, both with respect to individual type segments and construction year cohorts of the stock. It is also highly uncertain how such effects are likely to emerge over time in future.

The aim of the scenario analyses carried out in the Norwegian EPISCOPE pilot actions is to examine possible aggregated effects of different renovation ambitions for the Norwegian national building stock towards 2050. This is done by estimating annual changes in stock size, composition and characteristics, taking into consideration also the future ageing of existing buildings and addition of new buildings. With the use of average energy characteristics of different type/age segments of the stock, and common frequencies of energy-renovation activities, the aggregated energy-saving effect of such renovation activities at different ambition levels are calculated.

The focus of the scenarios are the long-term effects of different renovation ambitions for existing buildings, holding assumptions regarding energy standards of new buildings (built later than 2015) constant, and holding assumptions on the use of on-site energy generation constant. Thus, the main research question of the analyses is the following:

How will different renovation ambitions for building envelope components in the existing Norwegian residential building stock contribute to future reductions in delivered energy and how will these contribute to meet policy targets for greenhouse gas emissions?

With this starting point three scenarios are studied:

- Trend scenario: Energy intensity trends in the building stock during 1993-2012 linearly extrapolated towards 2050
- Scenario B: Conservative renovation – All buildings lifted to Level 2 (Variant V2) only when exposed to renovation all the way towards 2050
- Scenario C: Proactive renovation – All buildings lifted to Level 2 (Variant V2) before and Level 3 (Variant V3) after 2020 when exposed to renovation

While the Trend scenario takes energy intensity trend observations since 1993 as basis, Scenario B and C take advantage of the V1, V2 and V3 variants in the TABULA model and the datasets of the Norwegian Residential Building Typology brochure [NTNU/SINTEF 2014]. From these datasets are collected the specific delivered energy intensity results (kWh/m^2/year) for renovation variant V1, V2 and V3 for each type/age segment of the building stock, hence referring to the already defined renovation measures for building envelope components as they are specified in this brochure. V1 represents the dwelling in its original state, V2 the state after a standard type renovation, and V3 the state after an ambitious renovation.

The Norwegian Government earlier this year decided to adopt EU targets for greenhouse gas emissions, i.e. at least 40 % reductions by 2030 relative to 1990-level emissions [Klima- og miljødepartementet 2015]. However, no target is decided for 2050 and there is yet no specific target for individual sectors such as the building sector. Since the Norwegian energy mix (delivered to the residential building stock) is by far dominated by electricity, and mainly from domestically generated hydropower, there are actually very few possibilities for large emission reductions in the energy supply chain. This means that most of the emission reduction potential must be sought in the building system itself, either by reducing the net energy need as a result of building technology improvements or occupancy behaviour changes, or as a result of future large-scale implementation of on-site generation (such as solar PV).

On this background we have chosen to use the following individual benchmarks for CO_2 reductions in the scenario analysis of the Norwegian residential building stock: 40 % reduction by 2030, with linear extrapolations of 30 % reduction by 2020 and 60 % reduction by 2050, all relative to the actual CO_2 emission level caused by the Norwegian residential building stock in 1990. This means that the future Norwegian national individual benchmark for specific CO_2 emissions, when adjusting for the expected future aggregated reference floor area growth, will be 11.98 kg/m^2/year for 263 million m^2 (EPISCOPE reference area) in 2020, 9.47 kg/m^2/year for 285 million m^2 in 2030, and 5.56 kg/m^2/year for 324 million m^2 in 2050. For comparison, the values are 14.6 kg/m^2/year for 252 million m^2 in 2015.

Scenario Approach

The scenario approach uses a dynamic calculation model (developed in Matlab) with "two layers". The first layer is a long-term dynamic and mass-balance consistent model of the building stock itself, which quantifies the expected future annual in-use stock of dwellings (#) and reference floor area (m^2) on the basis of the assumed future demand, i.e. the assumed development in persons, persons per dwelling and reference floor area per dwelling [Sandberg et al. 2014a and 2014b]. This layer of the model also follows the ageing development of each type/age segment of the stock, with lifetime probability functions for when renovation activities and demolition of ageing dwellings are likely to happen. With a chosen renovation cycle of ‘x’ years, assumed to be representative for deep energy renovation cycles in the Norwegian residential building stock, the model predicts the number of dwellings and reference floor area in each type/age segment that is likely to be exposed to renovation for each year towards 2050. In a given scenario one may specify model input assumptions that reflect the nature of this scenario. Such inputs are those related to external drivers (i.e. the demand for dwellings and floor area), those related to lifetime probability functions of dwellings and renovation cycles, and those related to the share of people living in different types of dwellings (i.e. SFH and MFH) over time.

The second layer of the model is an energy and emission layer that is linked to the building stock layer. Here are provided as model input data energy intensity values (kWh/m^2/year) for different energy carriers, for each type/age segment of the stock and for each variant (V1, V2 and V3) that represent possible renovation levels. For a given scenario one must define the assumed renovation ambitions, which means deciding upon what are the energy intensity values for each type/age segment and renovation level, and when these are assumed introduced in the stock over time. This layer of the model also gives the assumed energy mix composition over time, and the life-cycle (direct + indirect) CO_2 emission coefficient (kgCO_2/kWh) of each energy carrier, in order to estimate the future annual profile of total CO_2 emissions (kgCO_2/year).

Data Sources

Data sources for building statistics are taken from the most recent data available by Statistics Norway [SSB 2014a and 2015a]. These are high quality accounts of the total Norwegian residential building stock, with data on number of buildings, number of dwellings and national reference floor area, for every municipality in the country, split for each type segment (SFH, TH, MFH, AB) of the stock, and for construction year cohorts as defined in the EPISCOPE project. Population projections are taken from Statistics Norway [SSB 2012], while future assumptions for persons per dwelling and reference floor area per dwelling are made on the basis of how past trends are likely to continue in future. Data sources for energy use in residential buildings are also taken from Statistics Norway [SSB 2014b], and supplemented by data from a potential and barrier study for energy savings in residential buildings in Norway [Enova 2012]. CO_2 emission coefficient values for different energy carriers are taken from a background document of a Norwegian Climate Calculator [CICERO 2012].

Description of the Basic Case and the Most Relevant Scenarios

The scenario analyses in the Norwegian EPISCOPE pilot actions all use the same input assumptions for the first layer of the model – the building stock layer – leading to the following future EPISCOPE reference area values; 252 million m^2 in 2015, 263 million m^2 in 2020, 285 million m^2 in 2030 and 324 million m^2 in 2050. Hence, these intermediate results represent a reference area growth of 13.1 % in 2030 and 28.6 % in 2050, relative to the 2015 value. Consequently, just in order to maintain the energy demand at today’s level (kWh/year) the specific energy intensity values (kWh/m^2/year) in 2030 and 2050 must be reduced by the same percentage levels.

The base case of the scenario analyses is an estimated 2015 EPISCOPE reference area of 252 million m^2 heated floor area, with an average delivered energy intensity of 154 kWh/m^2/year, a weighted average CO_2 emission coefficient of 0.095 kgCO_2/kWh and an emission level of 14.6 kgCO_2/m^2/year

The future energy mix is assumed, in all scenarios, to follow the same pattern towards 2050, and the energy mix in 2015 is assumed similar to the observed energy mix in 2013. Fuel oil and coal are assumed phased out linearly from 3.4 % in 2015 to zero in 2020, and replaced by district heating. From 2020 district heating is assumed to grow linearly from 3.7 % to 7.7 % in 2050. Fuel wood and biomass is assumed to decrease linearly from 17.4 % in 2015 to 13.0 % in 2050. Natural gas and liquid gas is assumed kept constant at the very low (share of 0.4 %) 2015 percentage level. Electricity is changing according to the balanced sum of 100 %, with a share between 75 and 79 % throughout the analysis period, which is indeed an extraordinary high share compared to most other countries. Overall, the Norwegian energy mix is dominated by electricity, followed by some fuel wood and biomass, plus a little district heating.

The Trend scenario extrapolates the annual 1993-2012 observed aggregated average energy intensity values (kWh/m^2/year) in the Norwegian residential building stock, and makes a linear extrapolation of this trend line all the way towards 2015. One may claim that this is a highly uncertain and maybe unrealistic scenario, since observed energy intensity improvements during a recent period of the past 20 years may not hold in linear projections for the next 35 years in future. On the other hand, such a kind of 'linear projection on the basis of an actually observed recent past' is fairly common in practice. Hence, this was chosen as the Trend scenario assumption regarding future energy intensity improvements.

The two other scenarios represent a 'conservative' (moderate ambitious) and a 'proactive' (highly ambitious) approach to how to mitigate energy use and CO_2-emissions by technology improvements in building envelope components. Scenario B, as the conservative scenario, assumes that all energy renovation measures in the residential building stock all the way towards 2050 are carried out according to variant V2 specifications in the Norwegian building typology brochure [NTNU/SINTEF 2014], reflecting a standard renovation for all dwellings that statistically will be exposed to renovation. On the other hand, Scenario C as a proactive scenario assumes that all energy renovation measures after 2020 are carried out according to variant V3 in the typology brochure, reflecting an ambitious renovation strategy to be practiced for all dwellings that statistically will be exposed to renovation between 2020 and 2050.

Renovation carried out before 2020 are assumed to follow the variant V2 specifications for both Scenario B and C, and they also assume that new buildings built between 2015 and 2020 meet the Norwegian TEK10 energy standard [KMD 2010], while new buildings built after 2020 meets the coming TEK15 standard (according to passive house standards) and the later the expected TEK20 standard (assuming close to NZEB standard). Hence, there is no difference between Scenario B and C with respect to the energy quality of future new buildings, only the energy quality of renovation measures for existing buildings that will be exposed to renovation as a result of their ageing (using a renovation cycle of 40 years).

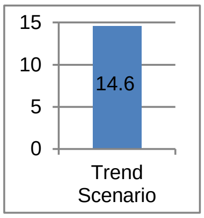
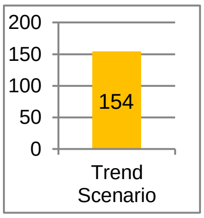
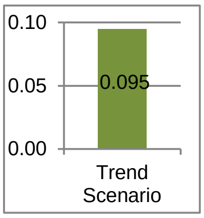
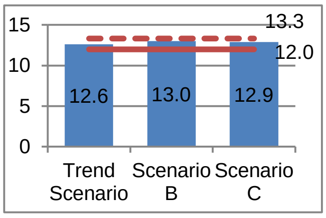
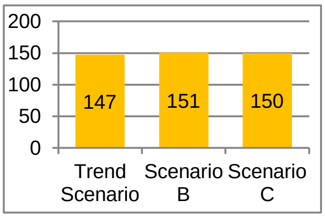
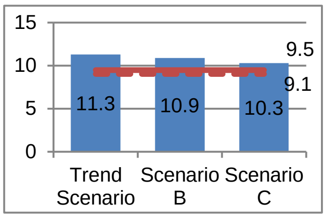
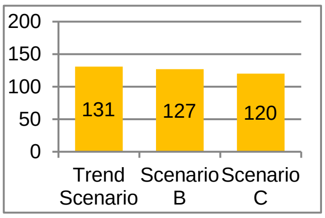
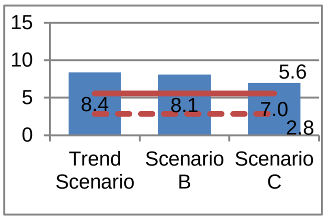
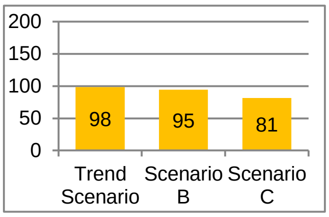
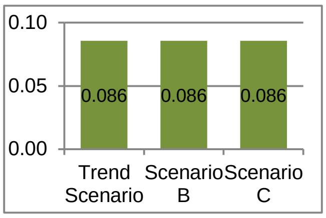
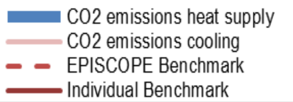
Results

Key results are shown in Table 41 and Table 42 below. In the base case of 2015 the estimated total final energy demand of the Norwegian residential building stock is 35,823 GWh/year, with an emission factor of 0.095 kg CO_2/kWh that gives total emissions of 3.68 million tons CO_2/year. This gives a specific total average heat demand of 154 kWh/m^2/year and a specific emission level of 14.6 kg CO_2/m^2/year.

All three scenarios give substantial reductions in annual total heat demand and CO_2 emissions compared to 2015, as shown in Table 41. The total average heat demand decreases from 154 kWh/m^2/year to a level of about 147-151 kWh/m^2/year in 2020, 120-131 kWh/m^2/year in 2030 and 81.4-98.4 kWh/m^2/year in 2050. With the assumed (small) changes in the energy mix, which in sum does not affect much the weighted average emission coefficient (down from 0.095 kg CO_2/kWh in 2015 to 0.086 kg CO_2/kWh in 2020, 2030 and 2050), these final energy saving improvements contribute to fairly large annual CO_2 emission reductions; going down from 14.6 kg CO_2/m^2/year in 2015 to 12.6-13.0 kg CO_2/m^2/year in 2020, 10.3-11.3 kg CO_2/m^2/year in 2030 and 7.0-8.4 kg CO_2/m^2/year in 2050.

Despite the significant growth in building stock reference area from 2015 to 2050, these emission intensity improvements (kg CO_2/m^2/year) yield significant overall emission reductions (tons CO_2/year) of some 8-10 % in 2020, 13-20 % reductions in 2030, and 26-39 % reductions in 2050, compared to the 2015 level. When compared to the (more) policy-relevant 1990 reference emission level – which was 4.50 million tons CO_2/year – the reductions are even larger; with some 25-26 % reduction in 2020, 29-35 % reduction in 2030, and 40-50 % reduction in 2050, depending on what scenario to look at.

Table 41: Summary Indicators <NO> Norway

	EPISCOPE Ref. Area	CO_2 emissions	Total heat demand	CO_2 emission factor heat supply
	10^9 m²	kg/(m²yr)	kWh/(m²yr)	kg/kWh
2015	0.25			
2020	0.26			
2030	0.29			
2050	0.32			
Explanation				
		$m_{CO2,heat\ supply}$: annual carbon dioxide emissions (related to EPISCOPE reference area) $m_{CO2,heat\ supply} = q_{total} \times f_{CO2,heat\ supply}$ 	q_{total}: total heat demand (heat generation for space heating and DHW, related to EPISCOPE reference area)	$f_{CO2,heat\ supply}$: total CO_2 emission factor of heat supply
Comments				
Trend Scenario: Energy intensity trends in the building stock during 1993-2012 linearly extrapolated towards 2050 Scenario B: Conservative renovation - All buildings lifted to Level 2 only when exposed to renovation all the way towards 2050 Scenario C: Proactive renovation - All buildings lifted to Level 2 before and Level 3 after 2020 when exposed to renovation				

These are all good news, showing potentials for large reductions in future final energy demand and CO_2 emissions in the Norwegian national residential building stock. However, unfortunately, these potential reductions are not sufficient to meet policy targets. EPISCOPE benchmark levels, as shown in Table 41, are well met in 2020 and are likely to be met in 2030, but not at all in 2050. The Norwegian (individual) benchmark levels are not met at any of the time steps in this analysis. The reason for the significant difference between the two benchmarks (EPISCOPE versus individual) is that the individual benchmark takes the actual Norwegian 1990 emission level (4.50 million tons CO_2/year) from the national residential building stock as starting point, while the EPISCOPE benchmark is derived with a common set of target factors for all countries in the project.

Table 42: Final energy by fuel <NO> Norway, gross calorific value [GWh/yr]

	2015	2020			2030			2050		
Absolute figures	Trend Scenario	Trend Scenario	Scenario B	Scenario C	Trend Scenario	Scenario B	Scenario C	Trend Scenario	Scenario B	Scenario C
natural gas	41	41	42	41	39	38	36	33	32	28
liquid gas	105	104	107	106	101	98	92	86	83	71
oil	1229	0	0	0	0	0	0	0	0	0
coal	5	0	0	0	0	0	0	0	0	0
wood / biomass	6222	5973	6118	6082	5337	5169	4885	3823	3675	3164
district heating	1103	1333	1365	1357	1740	1685	1593	2258	2171	1869
electric energy (used for heat supply)	27119	28209	28898	28727	27194	26339	24891	23148	22250	19157

Conclusions

The overall findings of the scenario analyses indicate that, in addition to the positive effect of high energy standards of new buildings to be constructed in the future, which also replace retiring buildings that will be demolished as a result of their high age, renovation activities in the standing building stock will effectively contribute to large and highly needed overall reductions in future energy use and CO_2 emissions.

There is not a very large difference between the three scenarios, however, the Trend scenario represents the highest level for energy use and emissions in 2030 and 2050. Clearly, in order to meet policy targets, more ambitious measures have to be taken than what has been realized from renovation activities that have been implemented between 1993 and today. The future will be more challenging than the recent past!

As expected, there is a significant difference in the overall results between Scenario B and C, particularly from 2030 to 2050. Hence, it will be important to develop policy instruments that facilitate the implementation of ambitious renovation measures, i.e. such measures that correspond to variant V3 specifications in the Norwegian Residential Building Typology Brochure and are made use of in Scenario C. Realistically speaking, this proactive scenario is well beyond what is likely to be implemented in practice, not because of the technical realism of variant V3 measures, but due to the likely high investment costs and the low chances that *all buildings* that from a (mathematical) modelling perspective are candidates for energy renovation will be actually lifted to such an ambitious variant V3 level after 2020. Most likely a share of these buildings will be lifted only to the variant V2 level, which is used as assumption in Scenario B, and some not be lifted in energy-standard at all. This means that future renovation measures in the Norwegian residential building stock in practice will probably be carried out at an ambition level somewhere between Scenario B and C.

In order to reach the policy targets that are represented by the EPISCOPE or individual benchmark levels in this study, other types of measures than technical improvements in the building envelope components have to be taken. These types can be grouped in three classes: a) changes in the energy supply system, towards less carbon-intensive energy carriers and lower energy distribution and conversion losses, aiming for an overall lower emission factor of the energy mix, b) changes in building occupancy behaviour, aiming for lower energy demand and an improved energy use culture in the population, and c) a large-scale proactive implementation of on-site energy generation and NZEB concepts also for existing buildings, carried out when such buildings are to be renovated or independent of this. The type a) measures are not likely to hold any significant potential for Norway, due to the already low-carbon energy mix in the country. On the contrary, the future energy mix may become more ’dirty’ due to a higher integration with the European electricity grid. This leaves us with the type b) and c) measures, which probably will both be needed, in parallel to the technical improvements in building envelope components.

Sources / References <NO> Norway

Table 43: Sources / References <NO> Norway

Reference shortcut	Concrete reference (in respective language)	Short description (in English)
[CICERO 2012]	Center for International Climate and Environmental Research (CICERO) (ed.) (2012): Kalkulator for beregning av klimagassutslipp fra husholdninger. Bakgrunnsdokument oppdatert av CICERO Senter for klimaforskning, MiSA og Østfoldforskning. Desember 2012.	Background document for a Climate Calculator for greenhouse gas emissions from households.
[Enova 2012]	Enova (ed.) (2012): Potensial- og barrierestudie: Energieffektivisering av norske boliger. Bakgrunnsrapport. Enova rapport 2012:01.1	Background report for the evaluation of potentials and barriers for energy savings in Norwegian dwellings.
[Klima- og miljødepartementet 2015]	Klima- og miljødepartementet (ed.) (2015): Ny utslippsforpliktelse for 2030 – en felles løsning med EU. Meld. St.13 (2014-2015) Melding til Stortinget. Avialable at: https://www.regjeringen.no/contentassets/07eab77cc38f4085abb594a87aa19f10/no/pdfs/stm201420150013000dddpdfs.pdf [2015-08-13]	Norwegian Government White Paper on climate change policy and new emission targets for 2030.
[KMD 2010]	Kommunal- og moderniseringsdepartementet (2010): Forskrift om tekniske krav til byggverk (Byggteknisk forskrift TEK10). Lovdata, sist endret 01.07.2015.. Avialable at: https://lovdata.no/dokument/SF/forskrift/2010-03-26-489 [2015-08-13]	Current (2010) regulations for building quality in Norway.
[NTNU/SINTEF 2014]	Brattebø, H./O'Born, R./Satori, I./Klinski, M./ r Nørstebø, B. (2014): Typologier for norske boligbygg – Eksempler på tiltak for energieffektivisering. NTNU/SINTEF, Trondheim. Available at: http://episcope.eu/fileadmin/tabula/public/docs/brochure/NO_TABULA_TypologyBrochure_NTNU.pdf [2015-07-05]	Norwegian Building Typology Brochure, published in the fragework of the EPISCOPE project
[Sandberg et al. 2014a]	Sandberg, N./Satori, I./ Brattebø, H. (2014): Using a dynamic segmented model to examine future renovation activities in the Norwegian dwelling stock. *Energy and Buildings.* Vol. 82, October 2014, 287–295. Available at: http://www.sciencedirect.com/science/article/pii/S0378778814005398 [2015-08-13]	Research paper on building stock dynamics modeling
[Sandberg et al. 2014b]	Sandberg, N./Satori, I./ Brattebø, H. (2014): Sensitivity analysis in long-term dynamic building stock modeling - Exploring the importance of uncertainty of input parameters in Norwegian segmented dwelling stock model. *Energy and Buildings.* Vol. 85, December 2014, 136–144. Avialable at: http://www.sciencedirect.com/science/article/pii/S037877881400721X [2015-08-13]	Research paper on building stock dynamics modeling
[SSB 2012]	Statistics Norway (2012): Befolknings-framskrivninger, 2012-2100. Available at: https://www.ssb.no/befolkning/statistikker/folkfram/aar/2012-06-20 [2015-08-13]	Population projections for Norway 2012-2100
[SSB 2014a]	Statistics Norway (ed.) (2014): Norges boligstatistikk 2013. Excel-fil levert fra SSB til NTNU for bruk I EPISCOPE-prosjektet.	Detailed accounting Excel file of the Norwegian dwellings, by numbers and floor area, for each type/age cohort and municipality by 2013-12-31.
[SSB 2014b]	Statistics Norway (ed.) (2014): Energy consumption in households, 2012. Statistics Norway. https://www.ssb.no/en/husenergi/ [2015-06-30]	Recent statistics of the use of energy and heating equipment in Norwegian dwellings.
[SSB 2015]	Statistics Norway (ed.) (2015): Dwellings, 1 January 2014. Available at: http://ssb.no/en/bygg-bolig-og-eiendom/statistikker/boligstat/aar/2015-04-22 [2015-06-30]	Profile of the Norwegian dwelling stock 1 January 2014

3.9 <SI> Slovenia

National Residential Building Stock

(by EPISCOPE partner ZRMK)

Observed Building Stock and Aims of the Scenario Analysis

The Slovenian pilot project on national scale of EPISCOPE concerns the housing stock of the residential buildings in Slovenia, which has set ambitious goals for energy efficiency related to national plans [MzI 2015b], [MzI 2015b]. National goals for 2030 are:

- Reduction of final energy consumption in buildings by 30 % compared to 2005;
- At least two thirds of energy consumption in buildings from generated from renewable sources;
- Reduction of GHG emissions in buildings by at least 70 % compared to 2005;
- To reduce particulate matter emissions from energy use in buildings by 50 % during the period 2015-2030.

Table 44: Scope of the observed building stock in <SI> Slovenia [SURS 2015a], [GURS 2015]

Scale	No. of dwellings	No. of buildings	No. of inhabitants	m² national reference area	m² EPISCOPE reference area
national	~ 844,000	~ 523,850	~ 2 million	~ 64.9 million (useful area)	~ 71.39 million

The challenge of the existing housing stock for the long term in Slovenia is to tackle the thermal efficiency of the housing stock, much of which is older and/or ‘harder to treat’. The IEE EPISCOPE project is intended to highlight where the initial potential for refurbishment exists and in which types of households. A key aim of the project is to evaluate more realistic refurbishment scenarios.

The targets for emissions are intended across all sectors as a whole, rather than for housing in particular. In practice each sector may have more or less to contribute in terms of savings towards the total budgets into the future, however for modelling purposes in this project it is assumed that housing will aim to meet the targets as given.

Scenario Approach

The scenario approach uses a calculation model (developed in MO Excel and M Visual basic) with “three layers”. The first layer is a long-term model of the building stock. It quantifies the expected future annual in-use stock of dwellings (#) and reference floor area (m^2) on the basis of the assumed past and future demand, i.e. the assumed development in persons, persons per dwelling and reference floor area per dwelling, potential for (partial/full/deep) renovation, based on the assumption for renovation and new build rates.

This layer of the model also follows the ageing development of each type/age segment of the stock, with predicted lifetime of building component and it’s technologies for heating and DHW, after which the building becomes the potential for renovation. Based on the renovation rates for each age band, buildings in each year, the model identifies the buildings for renovation, respective to their age of construction, renovation and architectual type. The second layer of the model is an energy and emission layer. Here are provided as model input data energy intensity values (deriving from typology [ZRMK 2012a], [ZRMK 2012b] and EPCs

[EPC 2015]), for different energy carriers, for each type/age segment of the stock and for each scenario. The last layer takes into account local or national plans, which can be implemented into a model on several different ways, e.g. more intensive renovation rates in specific year due to increased subsidies fund, increased share of grid connections due to network expansion in a city district.

To be able to carry out a comprehensive analysis, all EPCs from the database [EPC 2015] were studied. In Slovenia, the EPC database collects data on the building stock, refurbishment measures, and the development of energy efficiency of buildings.

Data Sources

Several data sources were used in the model and analysis in order to ensure thorough, comprehensive and as realistic as possible. The model and analysis derive from next data sources:

- **Databases from Geodetic Administration of the Republic of Slovenia** [GURS 2015]
- **The National Action Plan for Energy Efficiency for 2014-2020** [MzI 2015a]
- **The Institute of Macroeconomic Analysis and Development of the Republic of Slovenia**: population projections are used for the observed period and the revised scenarios of economic development of Slovenia until 2030th [UMAR 2013]
- **Statistical Office of the Republic of Slovenia**: contains information on the number and area of completed dwellings (new construction, extensions, conversion according to the CC-SI classification), the number of demolished dwellings and others. [SURS 2015b]
- **Intelligent Energy Europe TABULA** [ZRMK 2012a], and [ZRMK 2014]
- **Register of Energy Performance Certificates** [EPC 2015]
- **Research of the energy efficiency in Slovenia** (2010, 2011, 2012 and 2013): survey results on efficient energy management presents 12 indicators in the key areas of energy consumption in households. Indicators show the status of the buildings and technical equipment of households with the intention of modernizing buildings and facilities, conduct and attitude to energy use, estimates of savings and CO_2 emissions [REUS 2013].

Description of the Basic Case and the Most Relevant Scenarios

The starting point, which determines the current state of the building stock and its energy balance is the basis from which arise all scenarios. The first step is to gather the data and to determine the potential for energy renovation. The current state of the building depends on its potential for renovation, where four possible levels of the current state are considered [ZRMK 2012b]:

- **Unrefurbished:** Based on the existing data, the building was not subjected to any renovation in the past, therefore it has potential for renovation on all components of the thermal envelope (walls, roof, and windows). Unrefurbished buildings can be subjected to partial, full and LE renovation.
- **Part_Renovation:** Based on the existing data, the building was subjected to renovation of two building construction (walls, roof or windows) in the past, therefore the building has potential on two components of the thermal envelope (walls, roof or windows). Buildings with partial renovation can be subjected to partial or full renovation.
- **Full_Renovation**: Based on the existing data, the building was subjected to renovation of three building constructions (walls, roof or windows) in the past, therefore the building has potential on one more component of the thermal envelope (walls, roof, and windows). Buildings with full renovation can be subjected to LE renovation only.

- **LE_Renovation**: the building was subjected to major renovation works in the past, all building constructions had been renovated and is thus considered as a building with low energy (LE) demand for space heating. Buildings with LE renovation are not considered as a potential for renovation.

One of these states was determined for each representative of building typoplogy of the building stock. Renovation rates in the model do not apply for rates of one building component only, e.g. 3 % of walls renovation, but apply to the extent of possible renovation (partial, full, low energy). Partial renovation in the model covers renovation works on building's envelope only, while full and LE renovation can include the replacement of a heat, DHW supply system, as well as installation of a mechanical ventilation system. All buildings cannot be renovated in one year only so the model is taking into account several limitations when renovating the building stock.

The model adopts Slovenian national strategy [MzI 2015a], where reference and intensive scenario are considered as a maximum renovation rate in the building category, as shown on Figure 17 below for single-family houses and for multi-family houses. The scenarios present a share of renovated buildings with respect to the total sum of usable floor area, where the usable surface of building subjected to partial renovations are taken into account with 0.5 factor, full and LE renovations are taken into account with factor 1.

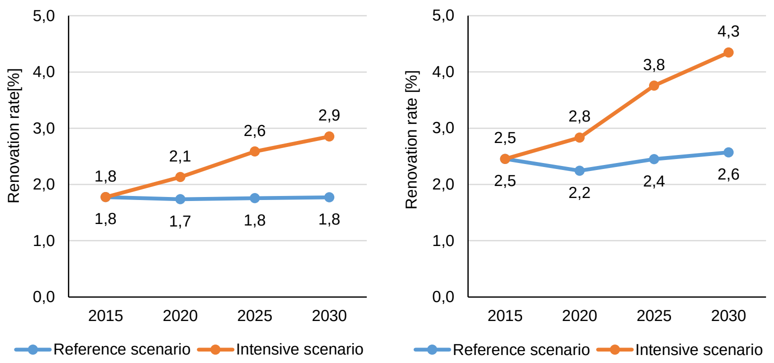


Figure 17: Renovation rate for single-family houses (left) and multi-family houses (right) from 2015 – 2030 according to the Slovenian national strategy [MzI 2015b]

Actual renovation rates can be deducted from two main sources – Register of Real Estates [REN 2014] (Table 45) and Eko sklad's subsides [Eko sklad 2009-2014] (Table 46). Fraction of renovation rates can be extracted from Eko sklad's subsidies in the 2008 – 2014 period. Fraction because not all building owners applied for subsidies, thus disabling to exactly determine the renovation rates.

In national strategic documents [MzI 2015a], [MzI 2015b] it is predicted that this subsidied rates accounts for approximately 1/3 of all renovation rates, meaning that renovations where building owners do not apply for subsidies, on average account for 2/3 of all renovation works. The reference scenario is based on the past renovation works and predicts slight improvement of the rates. Intensive, as the name suggest, predicts more intensive and bigger renovation rates.

The renovation rates in all scenarios take into account renovation of thermal envelope's components and replacement of generation systems. Taking into account lowering the share of fossil fuels heat generators (especially oil) and increasing share of RES technologies e.g. heat pumps and biomass boilers, due to large potential for exploitation of local forests.

Taking into account reference and intensive scenario in the future, we can deduct that renovation rates in single-family houses will be achieved, if the rates in the future will be similar as they were in the past years. It cannot be said exactly with the same amount of confidence for multi-family houses, since the rates from subsidies are below 1 %, while reference scenario predicts the rates over 2 % and the share of spontaneous rates it not accurate.

Table 45: Share of recorded renovation rates on thermal envelope only
(percentages relate to usable floor area) [REN 2014]

	Roof	Wall	Windows
2000	5.58 %	2.40 %	3.53 %
2001	3.57 %	1.49 %	2.14 %
2002	4.91 %	1.96 %	3.22 %
2003	4.25 %	1.80 %	3.01 %
2004	4.45 %	1.90 %	3.22 %
2005	5.10 %	2.30 %	3.80 %
2006	6.74 %	3.05 %	4.57 %
2007	1.77 %	1.13 %	1.58 %
2008	1.00 %	0.58 %	0.63 %
2009	1.09 %	0.76 %	0.62 %
2010	0.81 %	0.78 %	0.51 %
2011	0.71 %	1.02 %	0.28 %
2012	0.57 %	1.13 %	0.18 %
2013	0.19 %	0.24 %	0.10 %
2014	0.01 %	0.01 %	0.00 %

REN national survey was conducted in 2007/2008. After that, owner can report to the REN if they renovated the building envelope. The table above shows drop of renovation rates after 2007/2008. This is because owners do not report these events.

Table 46: Number of subsidised measures on residential buildings [Eko sklad 2009-2014]

Measure	2008	2009	2010	2011	2012	2013	2014
vacuum solar collectors	263	791	341	451	532	353	148
flat solar panels	443	1807	967	1236	1596	941	438
replacement of windows	5	1482	5315	6607	2504	1830	1061
biomass boiler – pellets	1	234	191	560	1776	2545	826
thermal insulation of facades	7	291	677	1338	1852	1932	1630
installation of heat pump air – water for DHW	0	0	174	1511	2995	2725	1304
thermal insulation of roofs	4	75	151	414	516	525	423
biomass boiler – firewood	1	316	376	752	1230	995	449
heat pump system air – water (Class 1)	0	0	9	187	575	1102	891
fireplace installation for central heating (pellets)	0	0	10	108	178	146	66
local ventilation with heat recovery	0	0	1	15	122	122	125
central ventilation with heat recovery	0	7	30	195	378	287	309
installation of heat pump system ground – water	0	7	56	177	280	214	154
heat pump air – water (Class 2)	0	0	35	209	736	1062	1009
thermostatic valves and hydraulic balancing	0	0	0	9	35	32	19

Reference and intensive scenario are taking into account as well the share of used technologies, which follows the national strategies and local state and limitations. Share of heat pumps and biomass boilers is slowly increasing, while share of energy carriers' oil and liquid gas is decreasing.

Results

Key results are shown in Table 47 and Table 48 below. In the base case of 2015 the estimated total final energy of the residential building stock in Slovenia is 10,789 GWh/year with an emission factor of 0.180 kg CO_2/kWh. This gives a specific total average heat demand of 122.81 kWh/m^2/year and a specific emission level of 22.2 kg CO_2/m^2/year.

Trend scenario, reference and intensive scenarios give substantial reductions in annual total heat demand and CO_2 emissions compared to 2015, as shown in Table 47. The total average heat demand decreases from 122.81 kWh/m^2/year to a level 103.1 – 117.7 kWh/m^2/year in 2020, 82.3 – 110.4 kWh/m^2/year in 2030 (depending on the scenario). With the given changes in the energy mix, the overall CO_2 emission factor decreases from 0.180 to 0.167 kg CO_2/kWh in trend scenario by 2020, although considerable improvements are recorded in annual CO_2 emissions. The later are reduced from 22.2 kg CO_2/m^2/year in 2015 to 11.5 – 19.7 kg CO_2/m^2/year in 2020, 8.5 – 15 kg CO_2/m^2/year in 2030.

Despite the significant growth in building stock reference area by 11.2 % from 2015 to 2030, these emission intensity improvements yield significant overall emission reductions (tons CO_2/year) of 11 – 48 % in 2020 and 33 – 62 % reductions in 2030, compared to the 2015 level, where buildings emit 1,581 kt of CO_2 emissions.

All the observed scenarios show great promise in the fulfilling the national goals for the reduction of final energy use and GHG emissions. According to policy targets and EPISCOPE benchmark levels, shown in Table 47 are met in both the observed years – 2020 and 2030. Policy target for the reduction of GHG emissions in buildings by 2030 at least 70 % compared to 2005 is achieved (Figure 18). Figure 18 shows the reduction of GHG emissions for all reference scenarios.

Emissions of existing buildings in 2015 amounted to 1,208 kt CO_2. The later by 2020 reduce to 971 kt CO_2, by 2030 to 657 kt CO_2. Emissions are reduced in 2020 to 58 % in 2030 and 72 % lower compared to base year 2005. Total emissions of existing and new buildings are slightly higher, and in 2030 estimated at 675 kt, which represents 71 % decrease compared on emissions in 2005 (Figure 18).

The trend from 2005 to 2013 is the result of past action and shows the actual recorded emisions. Such a large rise and then again a drop is mainly due to the use and then replacement of oil as energy carrier on account of increased use of biomass, due to its large potential. The red line on Figure 18 presents the expected results from reference scenario, where the share of RES technologies is going to increase, replacing the CO_2 wasteful technologies.

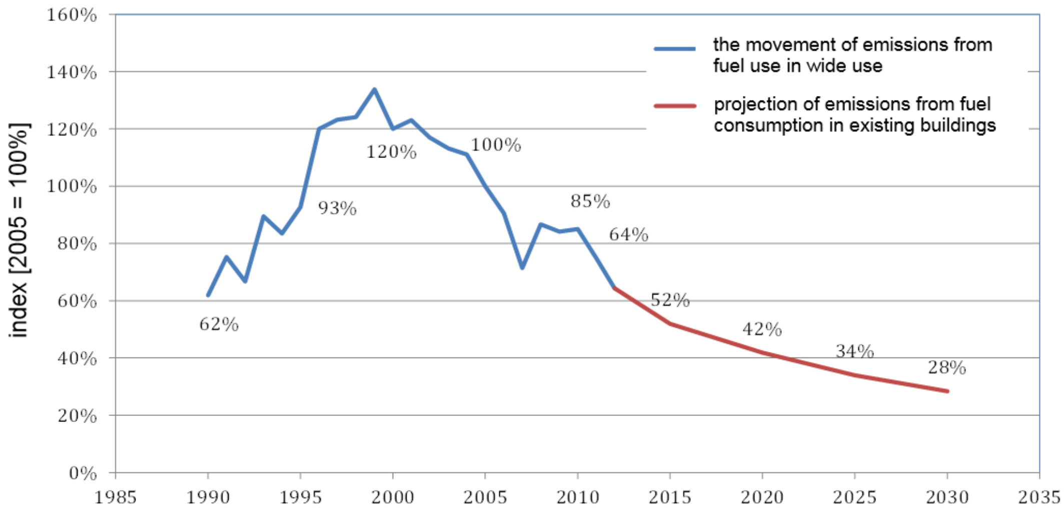


Figure 18: Changes in GHG emissions from fuel consumption in existing buildings and projections for the period 2015-2030 [MzI 2015b]

Table 47: Summary Indicators <SI> Slovenia

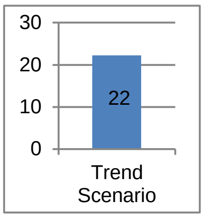
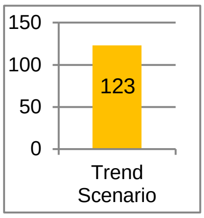
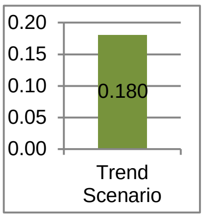
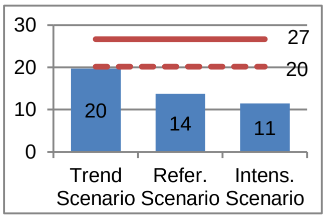
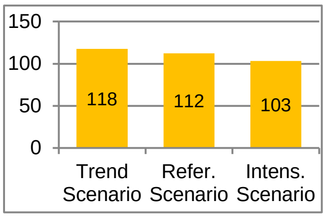
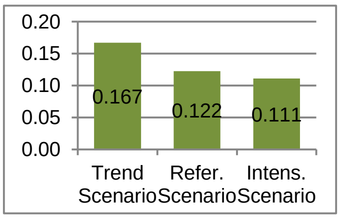
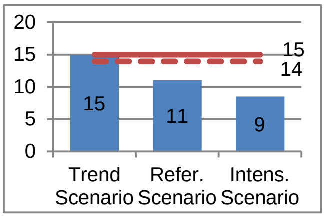
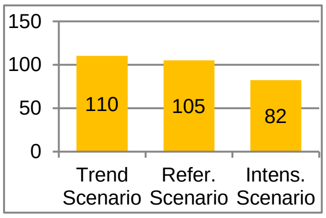
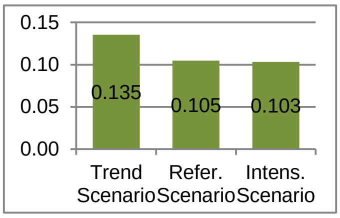
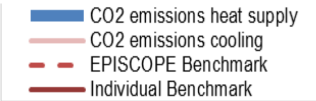
	EPISCOPE Ref. Area	CO_2 emissions	Total heat demand	CO_2 emission factor heat supply
	10^6 m²	kg/(m²yr)	kWh/(m²yr)	kg/kWh
2015	71.39			
2020	74.47			
2030	79.42			
2050				
Explanation				
		$m_{CO2,heat\ supply}$: annual carbon dioxide emissions (related to EPISCOPE reference area) $m_{CO2,heat\ supply} = q_{total} \times f_{CO2,heat\ supply}$ 	q_{total}: total heat demand (heat generation for space heating and DHW, related to EPISCOPE reference area)	$f_{CO2,heat\ supply}$: total CO_2 emission factor of heat supply
Comments				

Table 48: Final energy by fuel <SI> Slovenia, gross calorific value [GWh/yr]

	2015	2020			2030			2050		
Absolute figures	Trend Scenario	Trend Scenario	Reference Scenario	Intensive Scenario	Trend Scenario	Reference Scenario	Intensive Scenario			
natural gas	1305	1313	1139	1153	1141	1056	1000			
liquid gas	180	146	139	128	127	111	97			
oil	1570	1087	1056	611	446	403	333			
coal	2	1	0	0	1	0	0			
wood / biomass	5385	4560	3556	3542	3266	2750	2528			
district heating	886	799	583	611	528	556	514			
electric energy (used for heat supply)	1036	1027	528	528	967	550	528			
solar energy	124	160	33	44	220	50	56			
geothermal energy	301	315	333	389	741	500	514			

Conclusions

The overall findings of the scenario analyses indicate that, in addition to the positive effect of high energy standards of new buildings to be constructed in the future, renovation activities in the existing building stock will effectively contribute to large and highly needed overall reductions in future energy use and CO_2 emissions.

There is a difference between the three scenarios, especially the intensive one. Intensive scenario predicts higher renovation rates and savings that are going to be hard to achieve. Hence, it will be important to develop policy instruments that facilitate the implementation of ambitious renovation measures, i.e. expansion of the local grid, renovation rates of at least 1.75 % in the single-family house sector and above 2.00 % in multi-family houses.

In order to reach the policy targets that are represented by the EPISCOPE or individual benchmark levels in this study, other types of measures than technical improvements in the building envelope components have to be taken. Changes in the general heat supply structure foresees replacement of old oil/coal/gas boiler for heating and/or DHW with new gas condensing boiler/heat pumps or with connection to the local district biomass heating. Implementation of energy efficiency measures for achieving the goals can be summarised in:

- Targeting subsidies to the full renovation. Continuation of the policy of promoting investment financial incentives (incentives Eco Fund). In the future, these incentives are more targeted, with the amount of incentives the comprehensive – full renovations of buildings will be stimulated more (maximum rate of co-financing will be part of the action comprehensive energy refurbishment of buildings, and the lowest execution of individual action). Subsidies should be linked also to check on the quality of realization of renovation.
- Renovation of neighbourhoods: the issue has to be addressed and examined, in order to find the instruments to promote the rehabilitation of the neighbourhoods.
- Focus on renovation to increase the rate – especially among the buildings built before 1980s – by increasing consultancy in energy efficiency measures, increasing the subsidies for the major renovations optimising the insolation thickness in relation to the life cycle of the building,
- Replacing fossil energy carriers through renewables systems, with the most promising being biomass boiler and heat pumps,
- Accelerate the trainings for the professionals for energy efficient and sustainable heating systems and constructors,
- Implementation of regular inspecting and optimising the heating systems,
- Increasing information campaigns not only for the energy efficiency in buildings and building compliances but also users' behaviour.

Additionally a movement to lower carbon society on a national scale will be needed to reduce the current electricity carbon factor. Further analysis, on either local or national level, can be carried out through visual presentation of analysis results, to further identify the best candidates in the national stock for refurbishment, which would help to inform the details of policies moving forward to help meet the carbon dioxide reductions required.

Geographic Information Systems (GIS) offers the opportunity to characterize building stocks in some systematic dimensions using geo-referenced information for buildings. The main objective of this is to present building stock's profile (e.g. consumption, potential and savings) through a GIS-based approach. To this goal, we developed an application with Google maps API, which enables a powerful way of presenting the energy balance of the building stock. An application was developed which shows several aspects of the building stock, resulting from the analyses.

Web application located at www.energetskaizkaznica.si\map shows the potential for renovation of thermal envelope's components. The buildings where roof, façade and windows are potential for renovation are marked as red with radius 3. Buildings with 2 components for renovation have radius 2, and buildings with potential for renovation of 1 component – radius 1. Imaging reveals that the vast majority of the buildings have a big potential for renovation on thermal envelope.

Sources / References <SI> Slovenia

Table 49: Sources / References <SI> Slovenia

Reference shortcut	Concrete reference (in respective language)	Short description (in English)
[Eko sklad 2009-2014]	Eko sklad (2009): Letno poročilo o dejavnosti in poslovanju Eko sklada, Slovenskega okoljskega javnega sklada v letu 2008, Ljubljana, marec 2009. Available at: http://www2.ekosklad.si/pdf/LetnaPorocila/LP_08_slo.pdf [2015-07-21] Eko sklad (2010): Letno poročilo o dejavnosti in poslovanju Eko sklada, Slovenskega okoljskega javnega sklada v letu 2009, Ljubljana, marec 2010. Available at: http://www2.ekosklad.si/pdf/LetnaPorocila/LP_09_slo.pdf [2015-07-21] Eko sklad (2011): Letno poročilo o dejavnosti in poslovanju Eko sklada, Slovenskega okoljskega javnega sklada v letu 2010, Ljubljana, marec 2011. Available at: http://www2.ekosklad.si/pdf/LetnaPorocila/LP_10_slo.pdf [2015-07-21] Eko sklad (2012): Letno poročilo o dejavnosti in poslovanju Eko sklada, Slovenskega okoljskega javnega sklada v letu 2011, Ljubljana, marec 2012. Available at: http://www2.ekosklad.si/pdf/LetnaPorocila/LP_11_slo.pdf [2015-07-21] Eko sklad (2013): Letno poročilo o dejavnosti in poslovanju Eko sklada, Slovenskega okoljskega javnega sklada v letu 2012, Ljubljana, marec 2013. Available at: http://www2.ekosklad.si/pdf/LetnaPorocila/LP_12_slo.pdf [2015-07-21] Eko sklad (2014): Letno poročilo o dejavnosti in poslovanju Eko sklada, Slovenskega okoljskega javnega sklada v letu 2013, Ljubljana, marec 2014. Available at: https://www.ekosklad.si/dokumenti/media/LetnaPorocila/LP_13_slo.pdf [2015-07-21]	Eko Fund - The Environmental Fund of the Republic of Slovenia. A review of subsidies in the housing sector for the period 2008-2014 – annual reports.
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[MzI 2015a]	Republika Slovenija Ministrstvo za infrastrukturo (2015): Akcijski načrt za energetsko učinkovitost za obdobje 2014–2020 (AN URE 2020). Available at: http://www.energetika-portal.si/fileadmin/dokumenti/publikacije/an_ure/an_ure_2020_sprejet_maj_2015.pdf [2015-07-21]	National Action Plan for Energy Efficiency for 2014-2020.

Reference shortcut	Concrete reference (in respective language)	Short description (in English)
[MzI 2015b]	Republika Slovenija Ministrstvo za infrastrukturo (2015): Dolgoročna strategija za spodbujanje naložb energetske prenove stavb. Available at: http://www.energetika-portal.si/dokumenti/strateski-razvojni-dokumenti/dolgorocna-strategija-za-spodbujanje-nalozb-energetske-prenove-stavb/ [2015-07-21]	Long-term strategy for mobilising investment in the renovation of the national stock
[REN 2014]	Geodetska uprava Republike Slovenije (2014): Register nepremičnin Slovenije	Registry of Buildings
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[ZRMK 2012a]	Rakušček, Andraž; Šijanec Zavrl, Marjana (2012): Slovenia. In: Diefenbach. N./Loga, T. (ed.) (2012): Application of Building Typologies for Modelling the Energy Balance of the Residential Building Stock. TABULA Thematic Report No 2. Institut Wohnen und Umwelt Gmbh; Darmstadt. Available at: http://episcope.eu/fileadmin/tabula/public/docs/report/TABULA_TR2_D8_NationalEnergyBalances.pdf [2015-07-27]	Aplikacija tehnologij pri modeliranju energijske bilance stavbnega fonda
[ZRMK 2012b]	Rakušček, Andraž; Šijanec Zavrl, Marjana; Stegnar, Gašper (2012): National Scientific Report – Slovenia. IEE TABULA – Typology Approach for Building Stock Energy Assessment. Gradbeni inštitut ZRMK; Ljubljana / Slovenija; May 2012. Available at: http://episcope.eu/fileadmin/tabula/public/docs/scientific/SI_TABULA_ScientificReport_ZRMK.pdf [2015-07-21]	Description of the typology approach for the assessment of the energy balance of building stock
[ZRMK 2014]	Šijanec Zavrl, Marjana; Rakušček, Andraž; Stegnar, Gašper (2014): Tipologija stavb energetska učinkovitost in tipične stavbe v Sloveniji. 2. Izdaja. Available at: http://episcope.eu/fileadmin/tabula/public/docs/brochure/SI_TABULA_TypologyBrochure_ZRMK.pdf [2015-07-21]	National typology brochure Slovenia, developed during the IEE Projects TABULA and EPISCOPE; Gradbeni inštitut ZRMK; Ljubljana / Slovenija 2011-2014

4 Summary

(by EPISCOPE partner IWU)

In the following, some main findings concerning the building stock models especially concerning the analyses of the current state, energy saving measures for target achievement as well as some general conclusions are summarised.

Building stock models – analyses of the current state

In most of the regional and national case studies existing building stock models were used and further developed. Some of the models are closely linked to classification, model buildings and/or energy performance levels of national residential building typologies (IT, NL, NO, SI). The models generally include certain assumptions for demolition and newly constructed dwellings.

Special attention was paid to modelling the basic cases close to reality. Apart from comparisons to national (or regional) energy balances in some cases also specific information about the ratio between measured and calculated consumption was used to calibrate the calculation model (GB, GR).

Different types of existing information sources were used to define the current states of the building stocks:

- General information (number of dwellings, living space, …) were usually derived from national housing surveys, published by national statistical agencies.
- Statistical information about the refurbishment state and the type and state of heat supply systems could in some case studies been derived from specific housing surveys (representative samples) also including energy-related aspects (DE, GB, GR, NO).
- The state of the existing stock could in one case study be extracted from a building stock database which was a full inventory of the respective housing portfolio (NL).
- In another case it was possible to derive information about the energy performance of the building components from an EPC database (GR). However, much effort was needed for plausibility checks since the data quality turned out to be not sufficient for these evaluations.
- It was also possible to evaluate databases of subsidy programmes (AT, SI) and demands for tax reduction (IT). Of course this information could only be used as a lower boundary to estimate the number of annual refurbishment, since the number and the quality of energy upgrades implemented without demanding grants is unknown.

The individually calculated delivered energy for the current states of the building stocks is displayed in Figure 19: The large variation of the total delivered energy per m² reference area is due to different mixes of building types and refurbishment states, but it is also due to different climatic data and utilisation conditions. Also the distribution of energy carriers is rather different.

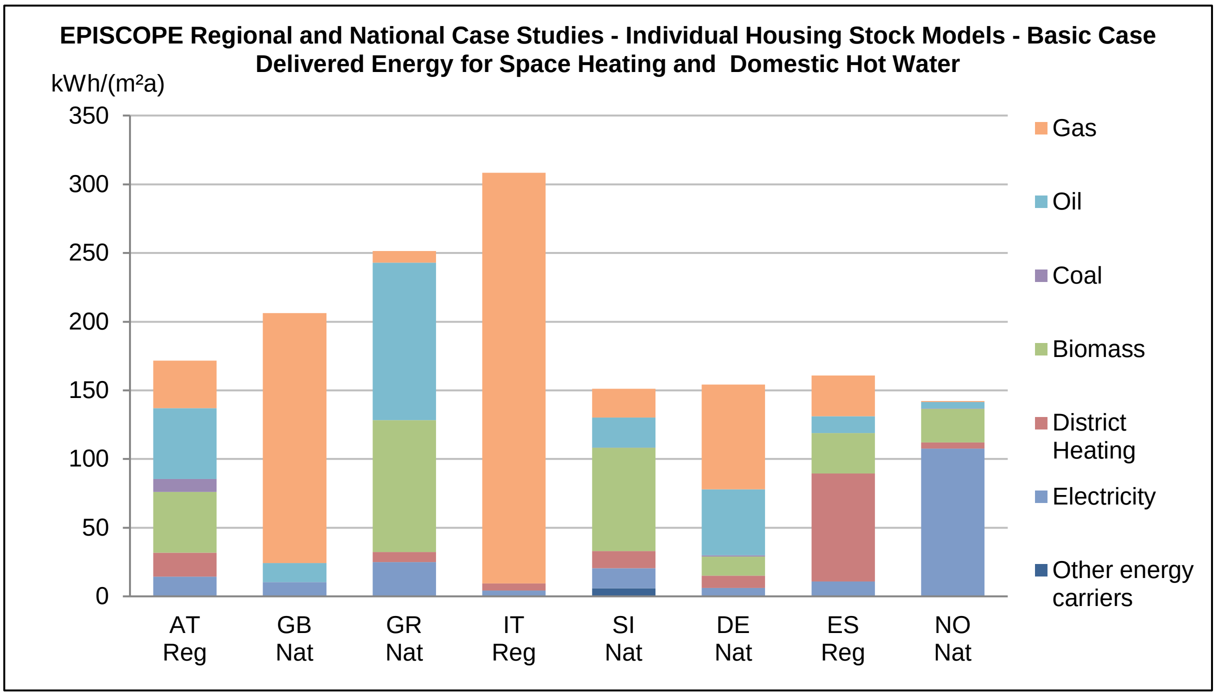

Figure 19: EPISCOPE regional and national case studies – delivered energy for heating and DHW per m² EPISCOPE reference area (see section 3) and year for the existing state (basic case)

The scenario analyses as well as the values included in Figure 19 have been determined by use of individual building stock models. To enable a comparison of input data and calculation results simplified building stock models have been defined for all case studies by use of the TABULA calculation procedure. These “average buildings” are being displayed by the TAUBLA WebTool[12].

Energy saving measures for target achievement

In general, energy saving measures were considered with regard to achieve individual (regional or national) or EU climate and energy targets. However, in the absence of specific individual targets for the building stocks the envisaged relative reductions of total emissions in the respective countries were used to determine corresponding targets for the housing sectors.

In contrast to the trend development the more ambitious scenarios are based on the assumption that annual rates as well as the insulation levels will be increased. In some of the ambitious scenarios the levels are oriented explicitly at the passive house (NO) or future NZEB standards (NL).

Furthermore, transitions to heat supply systems which are more efficient or include more renewables were considered in different ways: e.g. by switching to electrical heat pumps (assuming a prospective increasing share of renewables in the electric grid), by installation of thermal solar systems or by expanding biomass based district heating systems.

The discussion of the future building stock development includes also the question of demolition and the construction of new buildings. In the ambitious scenarios very high energy performance levels (e.g. NZEB standards) were assumed for newly built dwellings to minimise the effect of the increased total consumption caused by the reference area growth.

In Figure 20 CO_2 emissions for space heating and domestic hot water per m² TABULA/EPISCOPE reference area (see section 3) are shown for all trend scenarios calculated for the different building stocks. Furthermore, the EPISCOPE and individual national or regional benchmarks are displayed (description of benchmarks see chapter 3).

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[12] TABULA WebTool area “Building Stocks”: http://webtool.building-typology.eu

In nearly all cases (except SI) the current trend is not acceptable as a long term strategy and there is a necessity to apply more efficient and intense energy saving measures. This includes an augmentation of refurbishment rates, an augmentation of the share of deep refurbishments and a decarbonisation of the heat supply systems.

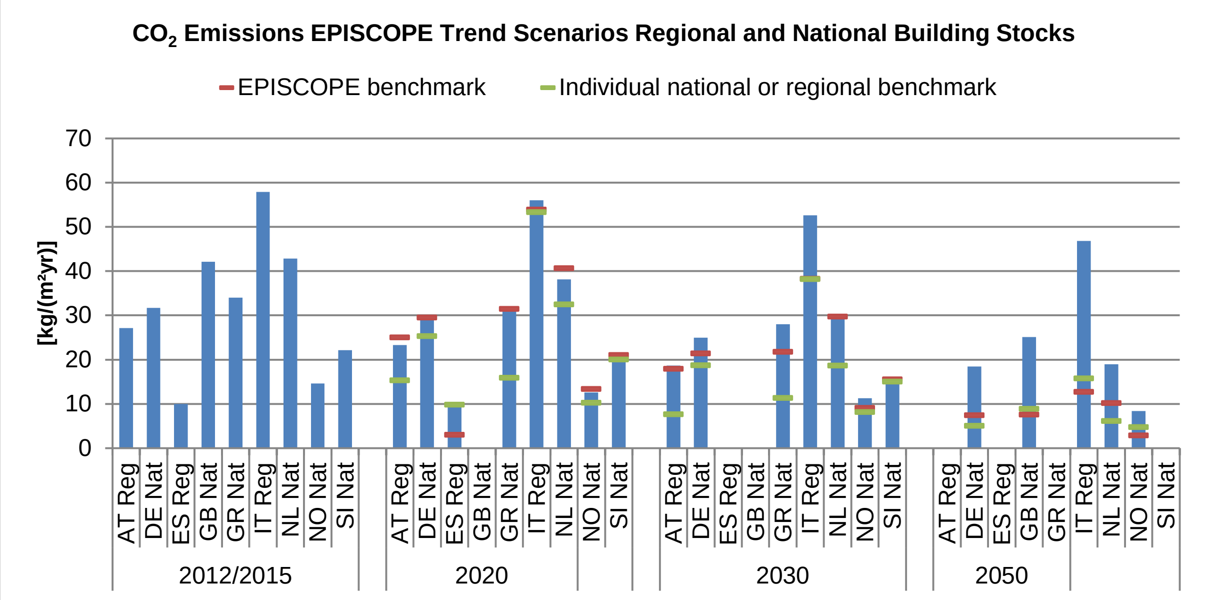

Figure 20: CO2 emissions for space heating and domestic hot water according to the EPISCOPE trend scenarios for regional and national building stocks, extrapolations of current improvement rates (in many cases partly based on assumptions)

Overview of partners' conclusions

For each case study individual conclusions and recommendations regarding refurbishment strategies but also methodical aspects have been eleaborated. They can be found in the individual national case study reports as well as (in summary) at the end of the respective case study section of this synthesis report. A more detailed discussion of the monitoring-related conclusions is also available in the EPISCOPE Synthesis Report N° 4 which is focused on building stock monitoring[13]. In the following an overview of the relevant key aspects mentioned by one or several partners is given:

Methodical questions

- Current refurbishment activities should be regularly measured e.g. by means of surveys in order to provide a solid foundation for scenario calculations and to make it possible to check if the carbon dioxide emission reduction of the building stock is on the right track.
- The quest for and access to data proved to be a great challenge (e.g. access to the detailed input energy audit data for generating EPCs). To support future work and further analysis, more good quality data would be valuable.
- The basic data of the models published in the case study reports, in tables including energy performance indicators and by means of average buildings are available for future use (common knowledge).[14] It is recommended to build on this information and to maintain it when scenarios are elaborated in the future.

[13] EPISCOPE Synthesis Report No. 4 "Tracking of Energy Performance Indicators in Residential Building Stocks" http://episcope.eu/fileadmin/episcope/public/docs/reports/EPISCOPE_SR4_Monitoring.pdf

[14] All collected information is available at the "case study" pages of the EPISCOPE website: http://episcope.eu/monitoring/case-studies/

- The developed building stock models can in the future also be used for sensitivity analysis in order to assess a sufficiently large number of scenarios to derive the optimum combination of modernisation rates that must be included in energy efficiency national action plans to meet national targets related to CO_2 reduction.
- Further analysis could be carried out to identify the best or hard to treat candidates for refurbishment.

Technological paths

- Realistic energy saving potentials by means of thermal insulation must be fully used to achieve the climate targets. Within a short period of time a significant increase of annual rates of refurbishment must be achieved, and high quality insulation standards should be applied.
- A step change in heating systems away from fossil fuels to electric is required, along with decarbonisation of the electricity supply. These changes seem likely to require large changes in policies in order to achieve in the relatively short timescale required. In this movement towards electricity heat pumps are supposed to play a predominant role. The use of near-surface and deep geothermal energy should be considered as far as possible.
- Further changes of the heat supply structure are needed with regard to biomass use (directly in the buildings or in district heating systems, preferably CHP biomass plants) and solar energy use (thermal and PV systems). In summer, the consumption of fossil fuels and biomass with its short potential should be avoided (e.g. by increasing installations of thermal solar systems and PV-supplied heat pumps for DHW).
- Facing the limited potential of renewable energy sources the reduction of the energy need of the buildings is a precondition to achieve high fractions of renewables.
- In addition to the technical measures changes in building occupancy behaviour, aiming for lower energy demand, less space per occupant and an improved energy use culture in the population are needed.

Implementation of refurbishment strategies

- It is necessary to maintain stable, long term and efficient regulatory and legislative framework. Building regulations should be improved regarding requirements for small and major renovations.
- Incentives like attractive subsidy programmes are likely to be needed to boost refurbishment rates and encourage high energy performance standards. Subsidies should be targeted to full refurbishments and linked also to quality assurance and energy performance monitoring. This should be accompanied by increasing energy consultancies and information campaigns.
- An important factor is the user behaviour. The improvement of thermal conditions by applying insulation and the reduction of costs for conditioning should not lead to wasteful demeanour. This could be addressed by local awareness raising campaigns and by monitoring activities.
- Furthermore, an acceleration of trainings for professionals for energy efficient and sustainable constructions and heating systems should be strengthened.
- Renovation of neighbourhoods should be addressed and explored more intensively, in order to enhance confidence in energy saving measures. Building pilot nearly-zero energy buildings (new build or refurbishments) in the city districts would provide best practice and confidence in the technologies to the local players.

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